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16 [*LAMONT PUBLIC UTILITY DISTRICT IS A SPECIAL DISTRICT AND A POLITICAL SUBDIVISION OF THE STATE OF CALIFORNIA,
   EXEMPT FROM PAYMENT OF COURT FILING FEES PURSUANT TO GOVERNMENT CODE SECTION 6103]
17

18   SUPERIOR COURT OF CALIFORNIA, COUNTY OF KERN

19   METROPOLITAN DIVISION

20   * * *

21 COMMUNITY RECYCLING & RESOURCE   ) CASE NO. S-1500-CV-275272-EB
   RECOVERY, INC., a California corporation and) *Complaint filed: 11/22/11*
22 LAMONT PUBLIC UTILITY DISTRICT, a public)
   entity,   ) **DECLARATION OF JESSE FREDERICK IN**
23   ) **SUPPORT OF PETITIONERS' REPLY TO**
            Petitioners/Plaintiffs,   ) **RESPONDENT'S OPPOSITION TO EX PARTE**
24   ) **APPLICATION FOR STAY OF ADMISTRATIVE**
        vs.   ) **ORDER REVOKING CONDITIONAL USE**
25   ) **PERMIT**
   COUNTY OF KERN, a public entity, and DOES 1) **[CCP §1094.5(g)]**
26 through 100, inclusively,   )
)
27 _____Respondents/Defendants._____)

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                                    1
   DECLARATION OF JESSE FREDERICK IN SUPPORT OF PETITIONERS' REPLY TO RESPONDENT'S OPPOSITION TO EX PARTE
                    APPLICATION FOR STAY OF ADMINISTRATIVE ORDER

I, JESSE FREDERICK, declare as follows:

Qualifications:

1.   I am the Vice President of WZI Inc. ("WZI"). For a number of years WZI has served as the principal environmental consultant to petitioner Community Recycling & Resource Recovery, Inc. I offer this declaration in support of Community's Application to Stay of Administrative Order Revoking Conditional Use Permit. I have personal knowledge of the facts set forth herein and if called to testify, I could and would competently testify thereto except as to those matters stated herein on information and belief and as to those matters I believe them to be true.

2.   WZI Inc. is an environmental and consulting engineering company, which offers professional and technical services in regulatory compliance (air, water, waste and noise), geoscience, hydrology, site characterization, hazardous waste management, energy studies and environmental impact assessment. My employees consist of a mix of professional engineers, geologists, and scientists. As the Vice President of WZI Inc., I am responsible for the overall management of engineers, scientists and technicians providing technical standards for all projects.   I have been professionally involved in fields related to environmental management since 1983. I have extensive experience in process evaluation and facility design including obtaining necessary permits licenses and approvals. (See my curriculum vitae attached hereto and incorporated herein as Exhibit A)

3.   During my term of military service with the United States Navy, I was trained as a naval nuclear plant operator. I received my B.S. in Chemical Engineering from Rose Hulman Institute of Technology in 1972. I served as a Manager of Environmental Affairs for a Dow Chemical subsidiary working on facility health and safety issues (involving numerous industrial facilities and remediation sites and 750,000 acres of oil, gas and coal properties) as well as environmental permitting and regulatory development in the U.S. and abroad.

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4. I have the following relevant registrations:

- State of Texas Registered Engineer

- State of California Accredited Lead Verifier of Greenhouse Gas Emissions Data, Executive Order H-09-63

5. I was the co-editor of Environmental Engineering for Exploration and Production Activities and served on the Environmental Health and Safety Committee of the Society of Petroleum Engineers. I am a member in good standing of: American Institute of Chemical Engineers, American Chemical Society, Society of Petroleum Engineers and Association of Energy Engineers.

6. I jointly hold patents for Patent Nos. US 6,659,178 B2 Apparatus and Method for Sealing Well Bores and Bore Holes, US 6,860,997 B1 Apparatus and Method for Processing Organic Materials. I hold Patent No. 5,304748 Apparatus and Method for Steam Silencing and have several patents pending.

I have been a testifying expert in federal and state of California courts on matters related to environmental regulations and have testified as an expert on economics and environmental externalities of proceedings heard before Public Utility Commissions. I have experience in many forms waste management including operation and design.

Composting As A Biochemical Processes

7. Composting is the biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land. Aerobic composting is the decomposition of organic substrates (having a basic chemical makeup $C_XH_XO_XN_X$) in the presence of oxygen (air). Composting converts otherwise putrescible materials and destroys organic pathogens to humans, plant diseases, weed seeds, insects and insect eggs as well. (Exhibit B, Haug, R.T., The Practical Handbook of Compost Engineering, Lewis Publishers, CRC Press LLC., 1993)

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DECLARATION OF JESSE FREDERICK IN SUPPORT OF PETITIONERS' REPLY TO RESPONDENT'S OPPOSITION TO EX PARTE APPLICATION FOR STAY OF ADMINISTRATIVE ORDER

8.   Composting also absorbs many odor causing chemical compounds due to: the complex cellulose/organic matter biochemical reactive complex, the metabolic heat produced and the digestive action of fungi and bacteria. Ultimately converting the complex to compost which is an organic soil conditioner that has been stabilized to a humus-like product that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and sorted without nuisance, and that is beneficial to the growth of plants.

9.   The primary metabolic products released from the composting windrows are carbon dioxide, water and heat. Small quantities of ammonia, acetic acid, propionic acid, butyric acid, citric acid, pyruvic acid, organic sulfides (such as dimethyl sulfide and dimethyl disulfide) as well as various terpenes which have odors such as essential oils like limonene, geranium, rose, peppermint turpentine, and eucalyptus (cineol) which in combination contribute to the complex smell (especially in the early stages) of a healthy aerobic composting operation.

Importance Of Moisture In The Biochemical Process

10.   Continuous composting biochemical kinetics involve the balance within the biochemical reactor environment (windrows in this instance) for the desired microbial action and the continuous mass and energy balance to achieve a steady operation until such point that the digestible materials are consumed and the process gradually shuts down as the active microbes starve. The importance of water is best understood in the composting process' mass and energy balance, where water first enters the system in the form of intrinsic moisture carried with the digestible organics. As the composting process proceeds the microbes release water into the system along with metabolic heat. The circulation of air removes both water and heat through a psychrometric process (as an increase in the air's humidity) so as to maintain the necessary thermophilic system balance. The water carried away by the more humid exhausted air is essentially free of all non-volatile impurities and only contains the equilibrium concentration of any volatile compounds, thus digestible impurities introduced with the water are left in the biologically active environment for the microbes to feed on.

11. Balancing water and air is essential to the ultimate management of the composting operation. The ratio of water to non-water components of the feed stocks including bulking agents determines either the need for addition of water or the need for frequent turning of the material to dry the material and maintain a range of 40% to 80% moisture (depending on free air space and time in process) as the composting process proceeds from fresh mixed active piles to completely sterilized and biochemical stable compost, several months later.

12. At the end of this process, the compost is screened (separated) from the bulking agents and debris. The compost is prepared for final use and the recovered bulking agents are mixed with fresh bulking agent and added to other new windrows.

Proper Bulking Agent Design And Management Is Critical To Composting

13. The Community facility has sourced through special contracts, specific feed stocks (i.e., digestibles and bulking agents) diverted from landfills so that the individual windrows have a lower moisture ratio thus allowing the uptake of additional water during the early active phase of composting--in this instance the water is roughly 2 million gallons of daily waste water taken to relieve Lamont Public Utility District (LPUD).

14. During the first ten days, the biochemically driven oxygen consumption rate (which reflects the metabolic rate of conversion) is four times greater than the biochemically driven oxygen consumption in days eleven to twenty. After day 20 the biochemically driven oxygen consumption is dramatically reduced. CR&RR has specifically designed their windrow composition to take LPUD waste water during the first 15 days of a given windrow's reactive life cycle with optimal free air space, thereby exposing the pathogens to the highest biochemical activity where pathogen destruction rates are greatest. After 15 days, Community only uses well water to maintain the proper moisture content of the digestibles and bulking agents, thereby introducing no pathogens in that windrow during the later, slower, metabolic rate regime.

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DECLARATION OF JESSE FREDERICK IN SUPPORT OF PETITIONERS' REPLY TO RESPONDENT'S OPPOSITION TO EX PARTE APPLICATION FOR STAY OF ADMINISTRATIVE ORDER

15.   The mass of compostable feedstock (roughly 3000 tons per day of digestible and bulking agents) taken in allows a continuous adjustment of fresh starting compost mix to the desirable moisture content of approximately 70% moisture while also providing for evaporation due to aeration. The free air space in the windrows is initially controlled by adding certain bulking agents which also provides structural support in the composting matrix when it is controlled by turning.

Application Of Sewage Treatment Plant Waste Water In The Composting Process

16.   Composting provides a variety of synergies with Sewage Treatment facilities. First, the entire management of the water is within a controlled access location. Second, biochemical processes will safely consume the waste water and destroy pathogens. Third, the biochemically active fungi and bacteria will uptake metal salts and either hold them in the bulking agents or convert them to useable nutrients. Fourth, the aerobic composting process centralizes and absorbs source odors in waste water (Exhibit C, Metcalf and Eddy, "Wastewater Engineering Treatment Disposal and Reuse, 3rd ed., p89) Fifth, the composting operation can safely take sewage sludge (created by a treatment facility during cleanup operations) and safely digest it and use the resultant compost within the site for landscaping/non-agricultural application.

17.   In the absence of Community taking LPUD waste water, the Arvin/Lamont area is poor in waste water disposal options. The general location has no surface water outfall, leaving evaporation or percolation as the only potential means of eliminating water.

18.   The engineering perspective of life-cycle energy management for potentially biologically active waste water considers the need for energy to manage water. Irrigation of certain crops is sometimes described as a workable alternative, however, the piping costs, pumping costs, land application constraints and regulatory restrictions makes this a costly alternative.

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19. The surrounding area is almost entirely agricultural farmland with some food processing operations. Therefore, the land is frequently used for farming food for human consumption. Applying waste water to farmland used for food processing is prohibited by **California Code of Regulations Title 27).**

20. The cost of transport of the waste water includes the pumping requirement over several miles. Additionally, sufficient land must be controlled and public access must be limited by a suitable barrier. Assuming an optimal piping design, pumping would require 600,000 kW-h of electricity resulting in undesirable GHG (Green House Gas) emissions on the order of 150 Metric Tonnes of CO_2 per year. By contrast, Community is directly adjacent to the LPUD facilities and therefore the pumping requirement is negligible.

21. From a biochemical digestion standpoint the waste water from Lamont PUD, being mostly water, has a low concentration of digestible organic matter and must be combined with a much higher form of digestible material to take advantage of the metabolic destruction of human pathogens that may be present as part of the organic matter, which would otherwise be applied directly to land and crops.

The State Of California Requires That Kern County Recycle Waste And Relies On Recycling Facilities Such As Community To Meet Aggressive Mandatory Recycling Goals

22. The state of California has established certain goals for diversion of waste. This need has been defined in State Waste Management regulations and in the CARB's Scoping Plan to achieve reductions in Global Warming Gases. In 1989, AB 939 was passed which mandated local jurisdictions to meet solid waste diversion goals of 25 percent by 1995 and 50 percent by 2000. To increase waste diversion rates, each jurisdiction was required to consider waste normally disposed of into landfills and to create an Integrated Waste Management Plan.

23. Most recently, AB 341 was passed to encourage greater waste diversion from commercial and public entities such as prisons, public buildings, and other sources.

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24. The laws preamble states that it is the policy goal of the state that not less than 75% of solid waste generated be source reduced, recycled, or composted **by the year 2020,** …and the bill would … require a city, county, city and county, or regional agency to update all information required to be included in the non-disposal facility element."[emph] (Exhibit D, AB 341, passed Feb 10, 2011, Legislative Counsel's Digest)

25. As stated in the CalRecycle webpage, [t]he focus of the law is, "[t]o reduce greenhouse gas emissions by diverting commercial solid waste to recycling efforts and to expand the opportunity for additional recycling services and recycling manufacturing facilities in California."

26. A business which includes public entities generating more than four cubic yards of commercial solid waste per week or is a multifamily residential dwelling of five units or more is subject to the requirements under this law. Each jurisdiction is required to implement a commercial solid waste recycling program that consists of education, outreach and monitoring of businesses, that is appropriate for that jurisdiction and is designed to divert commercial solid waste from businesses. Each jurisdiction is required to report the progress achieved in implementing its commercial recycling program, including education, outreach, identification, and monitoring, and if applicable, enforcement efforts and exemptions, by providing updates in the electronic annual report.

27. By July 1, 2012, a business that generates more than four cubic yards of commercial solid waste per week or a multifamily residential dwelling of five units or more shall arrange for recycling services. By August, 2013, each jurisdiction shall report the progress achieved in implementing its commercial recycling program, including education, outreach, identification, and monitoring, and if applicable, enforcement efforts.

28. Currently, the state is at less than 50% total diversion, if the county is successful in closing the Community facility the progress made in the state's diversion program will be adversely impacted.

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29.   Although there is a large quantity of food scraps being disposed of in landfills, which CalRecycle identifies as an opportunity to recycle, only 16 facilities that CalRecycle surveyed reported processing residential and/or commercial food scraps and/or liquid wastes. A number of facility operators reported that planned food scraps collection programs had been postponed consistent with the housing slowdown and the poor economy.

30.   In 2007 California Integrated Waste Management Board (now CalRecycle) adopted Strategic Directive 6.1 calling for a reduction in the amount of organics in the waste stream by 50 percent by 2020. CalRecycle has estimated that "this will require an additional 50 to 100 organics processing and composting facilities". Given the current mix of facilities, 25 to 50 would most likely be composters. CalRecycle in its 2010 "Assessment of California's Compost and Mulch-Producing Infrastructure: Management Practices and Market Conditions" identified regulatory barriers, economic barriers, land use compatibility issues, and market barriers as factors precluding expansion of new construction needed to achieve their goal.

Continued Operation Of The Community Facility Is Integral To Meeting State Waste Diversion Mandates.

31.   Community receives approximately 25% of all compostable materials, making it the largest such operation, well beyond California's other largest composters (only 5% report processing 400 tons/day to 499 tons/day).   Replacing CR&RRs capacity today (permitted for 3,750 tons per day) would therefore require immediate permitting and construction of roughly 10 more of the typically largest composting operations (approximately 400 tons per day), above the 25 to 50 additional facilities already envisioned as necessary by CalRecycle to achieve its 2020 objective.

32.   In 2012, Community was cited for violations such as using: diverted gypsum wallboard for its sulfate content, recovering agricultural plastic from farmlands for reuse as ag-plastic products and crushing diverted demolished concrete for use on roads and parking lots for dust abatement.

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33.   Gypsum is commonly used in composting as an additive and in farming as a soil amendment.   Recycling of concrete is important to meeting continually increasing diversion requirements and dust control measures in the valley. Recycling of agricultural plastic is important to waste diversion and Green House Gas emissions reduction. There is a scientific dispute between the County and Community over the appropriate use of such materials. However, if Community's diversion of waste material ceases, existing landfills will again realize a proportionate increase in volumes otherwise diverted.

34.   Additionally, the local jurisdictions and state agencies will need to permit, build and operate 35 to 60 new composting facilities within the next 8 years, with 10 of these being at least 400 tons per day in size, to meet CalRecycling mandates, or face significant fines and penalties for non-compliance.

Future Benefits Of CR&RR Composting Operation And GHG Goals

35.   California Air Resources Board and CalRecycle (a member of the Climate Action Team) have worked closely to further the state's goals of achieving the 1990 emissions by 2020. CARB has identified in its 2011 publication titled, "METHOD FOR ESTIMATING GREENHOUSE GAS EMISSION REDUCTIONS FROM COMPOST FROM COMMERCIAL ORGANIC WASTE", (See Exhibit E, attached and incorporated herein) established a GHG emissions benefit of 0.42 metric tonnes of CO_2 equivalent (MtCO2e) per ton of feedstock.   Therefore, continued operation of the Community facility reduces California's GHG emissions by 575,000 MtCO2e per year.

36.   Plastic material reuse has been identified by CARB in its GHG plans. Utilizing recycled plastic saves 70% of the energy otherwise needed for production. CARB identified in its 2011 publication titled, "METHOD FOR ESTIMATING GREENHOUSE GAS EMISSION REDUCTIONS FROM RECYCING" (See Exhibit F, attached and incorporated herein), a GHG emissions benefit of 2.06 MtCO2e/ton of plastic or saving 2060MtCO2e per 1000 tons of plastic recycled. As required by the County, Community removed 25,000 tons of recovered plastic agricultural sheeting and drip irrigation components from property owned by the Fry Trust but not located on the property defined by the CUP. A one year supply of

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recovered plastic material translates to 51,500 MtCO2e per year of undesirable GHG emissions emitted to replace the plastic if the plastic is sent to the landfills rather than being recycled.

The County Claims Without Scientific Analysis Of Data By An Appropriately Qualified Expert, That H2S Caused The Deaths Of Two Community Employees

37. The county claim number 4 that: [o]n October 12, 2011, an accident occurred at the CRRR facility in which two employees of CRRR died due to exposure to hydrogen sulfide gas during maintenance of below ground on-site drainage materials.. (See Declaration of Lorelei Oviatt, pp. 6:28 -7:7) lacks scientific analysis of data by an appropriately qualified expert.

38. The claim is made that H2S was the cause of the deaths. No expert analysis of reliable data is provided to support this assumption. Requests for substantiation and monitoring data results were made to the Kern County Department of Environmental Health. However, as of the date of this declaration, no data has been provided. In the absence of data and appropriate expert scientific analysis, CalOSHA has not completed its investigation and has not determined a cause of the deaths. In conclusion, the County assumption that Hydrogen Sulfide caused the deaths or presents an imminent health and safety concern is scientifically unsupported.

39. Additionally, initial investigation of the site of the incident does not require a finding that H2S gas was present. H2S is present in every organic system having sulfurous compounds, including urban sewage systems, oilfield operations, dairies, waste water treatment, trash collection, etc., (Exhibit C, Metcalf and Eddy, "Wastewater Engineering Treatment Disposal and Reuse, 3rd ed., p89). H2S is a strongly pungent gas in low concentrations often described as having a rotten egg odor. It can be smelled at concentrations well below 1 part per million (ppm) in air. The odor increases as the gas becomes more concentrated, with the strong rotten egg smell recognizable up to 30 ppm. Above this level, the gas has a sickeningly sweet odor up to around 100 ppm. At concentrations above 100 ppm, a person's ability to detect the gas is lost due to temporary olfactory paralysis. (Exhibit G,

Canadian Association of Petroleum Producers, Occupational Health and Safety of Hydrogen Sulphide (H2S), March 2003) (Sax and Lewis, Dangerous Properties of Industrial Materials, 7th ed., p1912.)

40.   The first responder team E54, did not report a characteristic rotten egg odor nor did members of the team report that they smelled H2S. USAR 52 arrived shortly thereafter and found that their detection equipment did not properly function, [Exhibit H, Kern County Fire Department Report, Number11-31690]. Given that H2S has a recognition threshold of 0.0047 ppmv, if sufficient H2S was present to have killed the two victims, the first responder's should have smelled the lower concentrations of H2S when they were approaching the entrance to the drainage manhole in which the victims were found. They also did not report losing all sense of smell in the odor rich environment of the active compost site, which is often reported after smelling H2S.

41.   The Supervising Environmental Health Specialist, CUPA Inspector Vicky Furnish, took ILDH measurements but found that her instrument was not calibrated and once the calibration was performed, the results conflicted. Without any supporting data or scientific analysis, it is not surprising that her declaration attached to the County Opposition does not state that H2S was present or that H2S caused the deaths.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this 19th day of January, 2012, at Bakersfield, California.

JESSE D. FREDERICK

DECLARATION OF JESSE FREDERICK IN SUPPORT OF PETITIONERS' REPLY TO RESPONDENT'S OPPOSITION TO EX PARTE APPLICATION FOR STAY OF ADMINISTRATIVE ORDER

DECLARATION OF JESSE FREDERICK

I, JESSE FREDERICK, declare as follows:

Qualifications:

1.   I am the Vice President of WZI Inc. ("WZI"). For a number of years WZI has served as the principal environmental consultant to petitioner Community Recycling & Resource Recovery, Inc. I offer this declaration in support of Community's Application to Stay of Administrative Order Revoking Conditional Use Permit. I have personal knowledge of the facts set forth herein and if called to testify, I could and would competently testify thereto except as to those matters stated herein on information and belief and as to those matters I believe them to be true.

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DECLARATION OF JESSE FREDERICK

4.   I have the following relevant registrations:

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Composting As A Biochemical Processes

7.   Composting is the biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land. Aerobic composting is the decomposition of organic substrates (having a basic chemical makeup $C_XH_XO_XN_X$) in the presence of oxygen

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DECLARATION OF JESSE FREDERICK

(air). Composting converts otherwise putrescible materials and destroys organic pathogens to humans, plant diseases, weed seeds, insects and insect eggs as well. (Exhibit B, Haug, R.T., The Practical Handbook of Compost Engineering, Lewis Publishers, CRC Press LLC., 1993)

8.   Composting also absorbs many odor causing chemical compounds due to: the complex cellulose/organic matter biochemical reactive complex, the metabolic heat produced and the digestive action of fungi and bacteria. Ultimately converting the complex to compost which is an organic soil conditioner that has been stabilized to a humus-like product that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and sorted without nuisance, and that is beneficial to the growth of plants.

9.   The primary metabolic products released from the composting windrows are carbon dioxide, water and heat. Small quantities of ammonia, acetic acid, propionic acid, butyric acid, citric acid, pyruvic acid, organic sulfides (such as dimethyl sulfide and dimethyl disulfide) as well as various terpenes which have odors such as essential oils like limonene, geranium, rose, peppermint turpentine, and eucalyptus (cineol) which in combination contribute to the complex smell (especially in the early stages) of a healthy aerobic composting operation.

Importance Of Moisture In The Biochemical Process

10.   Continuous composting biochemical kinetics involve the balance within the biochemical reactor environment (windrows in this instance) for the desired microbial action and the continuous mass and energy balance to achieve a steady operation until such point that the digestible materials are consumed and the process gradually shuts down as the active microbes starve. The importance of water is best understood in the composting process' mass and energy balance, where water first enters the system in the form of intrinsic moisture carried with the digestible organics. As the composting process proceeds the microbes release water into the system along with metabolic heat. The circulation of air removes both water and heat through a psychrometric process (as an increase in the air's humidity) so as to maintain the necessary thermophilic system balance. The water carried away by the more humid exhausted air is essentially free of all non-volatile impurities and only contains the

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2 with the water are left in the biologically active environment for the microbes to feed on.

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4 operation.   The ratio of water to non-water components of the feed stocks including bulking

5 agents determines either the need for addition of water or the need for frequent turning of the

6 material to dry the material and maintain a range of 40% to 80% moisture (depending on free

7 air space and time in process) as the composting process proceeds from fresh mixed active

8 piles to completely sterilized and biochemical stable compost, several months later.

9 12.   At the end of this process, the compost is screened (separated) from the bulking agents

10 and debris.   The compost is prepared for final use and the recovered bulking agents are mixed

11 with fresh bulking agent and added to other new windrows.

12 **Proper Bulking Agent Design And Management Is Critical To Composting**

13 13.   The Community facility has sourced through special contracts, specific feed stocks

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15 have a lower moisture ratio thus allowing the uptake of additional water during the early active

16 phase of composting--in this instance the water is roughly 2 million gallons of daily waste

17 water taken to relieve Lamont Public Utility District (LPUD).

18 14.   During the first ten days, the biochemically driven oxygen consumption rate (which

19 reflects the metabolic rate of conversion) is four times greater than the biochemically driven

20 oxygen consumption in days eleven to twenty. After day 20 the biochemically driven oxygen

21 consumption is dramatically reduced.   CR&RR has specifically designed their windrow

22 composition to take LPUD waste water during the first 15 days of a given windrow's reactive

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24 biochemical activity where pathogen destruction rates are greatest.   After 15 days, Community

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18. The engineering perspective of life-cycle energy management for potentially biologically active waste water considers the need for energy to manage water. Irrigation of certain crops is sometimes described as a workable alternative, however, the piping costs, pumping costs, land application constraints and regulatory restrictions makes this a costly alternative.

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DECLARATION OF JESSE FREDERICK

consumption. Applying waste water to farmland used for food processing is prohibited by **California Code of Regulations Title 27).**

20.   The cost of transport of the waste water includes the pumping requirement over several miles. Addtionally, sufficient land must be controlled and public access must be limited by a suitable barrier. Assuming an optimal piping design, pumping would require 600,000 kW-h of electricity resulting in undesireable GHG (Green House Gas) emissions on the order of 150 Metric Tonnes of CO_2 per year. By contrast, Community is directly adjacent to the LPUD facilities and therefore the pumping requirement is negligible.

21.   From a biochemical digestion standpoint the waste water from Lamont PUD, being mostly water, has a low concentration of digestible organic matter and must be combined with a much higher form of digestible material to take advantage of the metabolic destruction of human pathogens that may be present as part of the organic matter, which would otherwise be applied directly to land and crops.

The State Of California Requires That Kern County Recycle Waste And Relies On Recycling Facilities Such As Community To Meet Aggressive Mandatory Recycling Goals

22.   The state of California has established certain goals for diversion of waste. This need has been defined in State Waste Management regulations and in the CARB's Scoping Plan to achieve reductions in Global Warming Gases. In 1989, AB 939 was passed which mandated local jurisdictions to meet solid waste diversion goals of 25 percent by 1995 and 50 percent by 2000. To increase waste diversion rates, each jurisdiction was required to consider waste normally disposed of into landfills and to create an Integrated Waste Management Plan.

23.   Most recently, AB 341 was passed to encourage greater waste diversion from commercial and public entities such as prisons, public buildings, and other sources.

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24.   The laws preamble states that it is the policy goal of the state that not less than **75%** of solid waste generated be source reduced, recycled, or composted **by the year 2020,** ...and the bill would ... require a city, county, city and county, or regional agency to update all information required to be included in the nondisposal facility element."[emph] (Exhibit D, AB 341, passed Feb 10, 2011, Legislative Counsel's Digest)

25.   As stated in the CalRecycle webpage, [t]he focus of the law is, "[t]o reduce greenhouse gas emissions by diverting commercial solid waste to recycling efforts and to expand the opportunity for additional recycling services and recycling manufacturing facilities in California."

26.   A business which includes public entities generating more than four cubic yards of commercial solid waste per week or is a multifamily residential dwelling of five units or more is subject to the requirements under this law. Each jurisdiction is required to implement a commercial solid waste recycling program that consists of education, outreach and monitoring of businesses, that is appropriate for that jurisdiction and is designed to divert commercial solid waste from businesses. Each jurisdiction is required to report the progress achieved in implementing its commercial recycling program, including education, outreach, identification, and monitoring, and if applicable, enforcement efforts and exemptions, by providing updates in the electronic annual report.

27.   By July 1, 2012, a business that generates more than four cubic yards of commercial solid waste per week or a multifamily residential dwelling of five units or more shall arrange for recycling services. By August, 2013, each jurisdiction shall report the progress achieved in implementing its commercial recycling program, including education, outreach, identification, and monitoring, and if applicable, enforcement efforts.

28.   Currently, the state is at less than 50% total diversion, if the county is successful in closing the Community facility the progress made in the state's diversion program will be adversely impacted.

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29.   Although there is a large quantity of food scraps being disposed of in landfills, which CalRecycle identifies as an opportunity to recycle, only 16 facilities that CalRecycle surveyed reported processing residential and/or commercial food scraps and/or liquid wastes. A number of facility operators reported that planned food scraps collection programs had been postponed consistent with the housing slowdown and the poor economy.

30.   In 2007 California Integrated Waste Management Board (now CalRecycle) adopted Strategic Directive 6.1 calling for a reduction in the amount of organics in the waste stream by 50 percent by 2020. CalRecycle has estimated that "this will require an additional 50 to 100 organics processing and composting facilities". Given the current mix of facilities, 25 to 50 would most likely be composters. CalRecycle in its 2010 "Assessment of California's Compost and Mulch-Producing Infrastructure: Management Practices and Market Conditions" identified regulatory barriers, economic barriers, land use compatibility issues, and market barriers as factors precluding expansion of new construction needed to achieve their goal.

Continued Operation Of The Community Facility Is Integral To Meeting State Waste Diversion Mandates.

31.   Community receives approximately 25% of all compostable materials, making it the largest such operation, well beyond California's other largest composters (only 5% report processing 400 tons/day to 499 tons/day). Replacing CR&RRs capacity today (permitted for 3,750 tons per day) would therefore require immediate permitting and construction of roughly 10 more of the typically largest composting operations (approximately 400 tons per day), above the 25 to 50 additional facilities already envisioned as necessary by CalRecycle to achieve its 2020 objective.

32.   In 2012, Community was cited for violations such as using: diverted gypsum wallboard for its sulfate content, recovering agricultural plastic from farmlands for reuse as ag-plastic products and crushing diverted demolished concrete for use on roads and parking lots for dust abatement.

33.   Gypsum is commonly used in composting as an additive and in farming as a soil amendment. Recycling of concrete is important to meeting continually increasing diversion

requirements and dust control measures in the valley. Recycling of agricultural plastic is important to waste diversion and Green House Gas emissions reduction. There is a scientific dispute between the County and Community over the appropriate use of such materials. However, if Community's diversion of waste material ceases, existing landfills will again realize a proportionate increase in volumes otherwise diverted.

34.   Additionally, the local jurisdictions and state agencies will need to permit, build and operate 35 to 60 new composting facilities within the next 8 years, with 10 of these being at least 400 tons per day in size, to meet CalRecycling mandates, or face significant fines and penalties for non-compliance.

Future Benefits Of CR&RR Composting Operation And GHG Goals

35.   California Air Resources Board and CalRecycle (a member of the Climate Action Team) have worked closely to further the state's goals of achieving the 1990 emissions by 2020. CARB has identified in its 2011 publication titled, "METHOD FOR ESTIMATING GREENHOUSE GAS EMISSION REDUCTIONS FROM COMPOST FROM COMMERCIAL ORGANIC WASTE", (See Exhibit E, attached and incorporated herein) established a GHG emissions benefit of 0.42 metric tonnes of CO2 equivalent (MtCO2e) per ton of feedstock.   Therefore, continued operation of the Community facility reduces California's GHG emissions by 575,000 MtCO2e per year.

36.   Plastic material reuse has been identified by CARB in its GHG plans.   Utilizing recycled plastic saves 70% of the energy otherwise needed for production. CARB identified in its 2011 publication titled, "METHOD FOR ESTIMATING GREENHOUSE GAS EMISSION REDUCTIONS FROM RECYCING" (See Exhibit F, attached and incorporated herein), a GHG emissions benefit of 2.06 MtCO2e/ton of plastic or saving 2060MtCO2e per 1000 tons of plastic recycled. As required by the County, Community removed 25,000 tons of recovered plastic agricultural sheeting and drip irrigation components from property owned by the Fry Trust but not located on the property defined by the CUP. A one year supply of recovered plastic material translates to 51,500 MtCO2e per year of undesireable GHG

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emissions emitted to replace the plastic if the plastic is sent to the landfills rather than being recycled.

The County Claims Without Scientific Analysis Of Data By An Appropriately Qualified Expert, That H2S Caused The Deaths Of Two Community Employees

37.   The county claim number 4 that: [o]*n October 12, 2011, an accident occurred at the CRRR facility in which two employees of CRRR died due to exposure to hydrogen sulfide gas during maintenance of below ground on-site drainage materials.. (See Declaration of Lorelei Oviatt, pp. 6:28 -7:7)* lacks scientific analysis of data by an appropriately qualified expert.

38.   The claim is made that H2S was the cause of the deaths. No expert analysis of reliable data is provided to support this assumption. Requests for substantiation and monitoring data results were made to the Kern County Department of Environmental Health. However, as of the date of this declaration, no data has been provided. In the absence of data and appropriate expert scientific analysis, CalOSHA has not completed its investigation and has not determined a cause of the deaths. In conclusion, the County assumption that Hydrogen Sulfide caused the deaths or presents an imminent health and safety concern is scientifically unsupported.

39.   Additionally, initial investigation of the site of the incident does not require a finding that H2S gas was present.   H2S is present in every organic system having sulfurous compounds, including urban sewage systems, oilfield operations, dairies, waste water treatment, trash collection, etc., (Exhibit C, Metcalf and Eddy, "Wastewater Engineering Treatment Disposal and Reuse, 3rd ed., p89). H2S is a strongly pungent gas in low concentrations often described as having a rotten egg odor. It can be smelled at concentrations well below 1 part per million (ppm) in air. The odor increases as the gas becomes more concentrated, with the strong rotten egg smell recognizable up to 30 ppm. Above this level, the gas has a sickeningly sweet odor up to around 100 ppm. At concentrations above 100 ppm, a person's ability to detect the gas is lost due to temporary olfactory paralysis. (Exhibit G, Canadian Association of Petroleum Producers, Occupational Health and Safety of Hydrogen
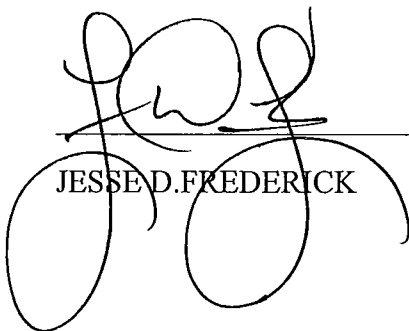
Sulphide (H2S), March 2003) (Sax and Lewis, Dangerous Properties of Industrial Materials, 7th ed., p1912.)

40.   The first responder team E54, did not report a characteristic rotten egg odor nor did members of the team report that they smelled H2S. USAR 52 arrived shortly thereafter and found that their detection equipment did not properly function, [Exhibit H, Kern County Fire Department Report, Number11-31690]. Given that H2S has a recognition threshold of 0.0047 ppmv, if sufficient H2S was present to have killed the two victims, the first responder's should have smelled the lower concentrations of H2S when they were approaching the entrance to the drainage manhole in which the victims were found. They also did not report losing all sense of smell in the odor rich environment of the active compost site, which is often reported after smelling H2S.

41.   The Supervising Environmental Health Specialist, CUPA Inspector Vicky Furnish, took ILDH measurements but found that her instrument was not calibrated and once the calibration was performed, the results conflicted. Without any supporting data or scientific analysis, it is not surprising that her declaration attached to the County Opposition does not state that H2S was present or that H2S caused the deaths.

       I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this 19th day of January, 2012, at Bakersfield, California.

JESSE D. FREDERICK

EXHIBIT "A"

WZI INC.

Resume for

Jesse D. Frederick

WZI Inc.

JESSE D. FREDERICK

WZI INC.

EDUCATION/CERTIFICATION:

USN, Surface Nuclear Mechanical Operator, 1974
B.S., Chemical Engineering, Rose-Hulman Institute of Technology, 1981
State of Texas Registered Professional Engineer
Member – American Institute of Chemical Engineering, Society of Petroleum Engineers,
American Chemical Society, Association of Energy Engineers
Dow Chemical, USA Environmental Management
GE Calma Computer Programming Training

SPECIAL CONTRIBUTIONS and RECOGNITIONS:

Recipient: Chevron Presidents Award for development of a new venture Business Plan
CoEditor: SPE Environmental Monograph Environmental Engineering for Exploration and
Production Activities
Guest Lecturer: Rose-Hulman Institute of Technology (1993) Advanced Coal Gasification
Technology, USC (2001) Electrical Deregulation, SPE (2002) Electrical Deregulation, EUEC
(2010)-Strategic Analysis of GHG Programs, Impacts on Reliability
Panelist – Valuing NO$_X$ Offsets, Panel Discussion, Sponsored by Air Quality Week, 1993
Patent for: Steam Blow Silencer, Well Abandonment Technology, Anaerobic Digester
IOGCC, Oil and Gas Exploration and Production Environmental Reporting Requirements
DOE, Title V Guidance Manual for E&P industry
National Petroleum Council, Peer Review for Studies on Natural Gas Pipeline Infrastructure,
1999
API, Toxic Release Inventory Report on Exploration and Production
Member of Texas NO$_X$ RACT Advisory Group, 1993Board Member: Kern Environmental
Education Program
Board Member: Society of Petroleum Engineers (San Joaquin Valley Chapter)
Member: Kern Economic Development Corporation, 1997-2011
Member: Kern County Electrical Restructuring Advisory Committee
Member: Kern County Chamber of Commerce Regulatory Advisory Committee

SPECIAL AREAS OF EXPERTISE:

- Contract assessment and negotiations.
- Business Planning including financial pro-forma and risk analysis.
- Gas and Electricity Price Forecasting and Refinery Margin Analysis.
- Participation in the sale and acquisition of large energy assets for Fortune 500
  Companies.
- Developed and implemented the audit procedure for cogeneration facilities and oil and
  gas producing properties for a Fortune 500 company.
- Oversaw the environmental aspect of the development process for over thirty power
  projects, through initiation to various stages of development including financial
  closing.
- Federal, state and local regulations, including FERC, NEPA, SEQRA, CEQA, PSD,
  NSPS, and NPDES as well as European environmental law.
- Expert testimony in both legal and semi-adjudicatory proceedings regarding: valuation of
  environmental externalities, energy values, facility siting, environmental dispatch,
  impact of standard offer contracts on property values, refinery product and property

valuation.
- Collaborated in the preparation of power project proposals. This included design and budgeting coordination for engineering, economic and engineering evaluations of various options.
- Forensic analysis of facility failures and on/offsite consequences.

PROFESSIONAL EXPERIENCE:

1994 - Present   <u>Vice President - WZI Inc.</u>

Responsible for the technical scoping of large projects which require multi-disciplinary integration. Responsible for technical peer review of on-going projects. Mr. Frederick acting on behalf of major clients has performed internal energy studies for long-term purchase and production plans as well as negotiated major energy contracts. In overseeing client regulatory compliance, Mr. Frederick advises clients regarding approaches to permitting and regulatory guidelines, including facilitating the Department of Energy's sale of the Elk Hills Naval Petroleum Reserve. Directs the planning, development and implementation of policies, programs and procedures in support of contract management. Mr. Frederick provides assistance in WZI's National Petroleum Council activities. Mr. Frederick is responsible for identifying business opportunities, expert advice on energy forecasts, valuations, business planning and provides business development services to numerous clients.

1995 - 1998   <u>President - CONSUMERS Utility Advisors, Inc.</u>

Provided staff leadership in strategic planning and technical negotiations for the emerging energy markets in California. Clients included Fortune 500 integrated energy companies. He also directed corporate activities including business development, goal setting and quality assurance. Mr. Frederick was responsible for business planning and economic models for various clients.

1982 - 1994   <u>Manager of Environmental Affairs, Destec Energy, Inc.</u>

Promoted from Project Development, Mr. Frederick provided analytical support for multi-million dollar projects. The increased need for firm project management in the area of environmentally related issues led to a promotion to establish the Environmental Affairs department for the Dow energy subsidiary and management of the day-to-day activities of the Environmental Affairs staff. In this role Mr. Frederick, reported to senior management and oversaw all domestic and international environmental issues related to energy production including: property sales and acquisitions, permitting, compliance, and facility/property audits for all Destec facilities including coal gasification projects, 740,000 acres of oil and gas properties, as well as superfund sites. Mr. Frederick wrote internal energy related planning documents for board implementation. Mr. Frederick was a team member for all business acquisitions and financial projects and participated in contracts and closings.

1981 - 1982   <u>Engineer, M.W. Kellogg</u>

Served in the Mechanical Division (Special Equipment Group) designing and procuring equipment related to refining and water treatment.

PUBLICATIONS:

Frederick, J. D., 1990, "Gas Turbine Emissions," Industrial Energy Technology Conference

Frederick, J. D. and B. Tulloh, 1991, "Title III of the Clean Air Act and BACT," Society of Petroleum Engineers Forum

Frederick, J. D., 1992, "Clean Air Act Title III and the Oil Industry," Society of Petroleum Engineers

Frederick, J. D., 1993, "Air Emissions Trading," SPE/EPA Exploration & Production Environmental Conference, San Antonio, TX, 7-10 March 1993

Frederick, J. D., 1993, "Effective Environmental Management," SPE Hydrocarbon Economics and Evaluation Symposium, Dallas, TX, 29-30 March 1993

Frederick, J. D. and S. Jenkins, 1993, "Cogeneration and Meeting California Environmental Requirements," 8th Cogeneration & Independent Power Congress, Boston, MA, 15-16 June 1993

Frederick, J. D. and W. Lessig, 1993, "Environmental Considerations of Coal Gasification Technology and the Wabash River Repowering Project," American Power Conference, Boston, MA, 1993

Frederick, J.D. and Wilson, M.J., 1993, Particulate Emission Testing Methodologies as Applied to Natural Gas Fired Turbines, S.P.E. Paper No. 25945

Frederick, J. D. and M.S. Weaver, 1997, *Title V and the Exploration and Production Industry*, S.P.E. Paper No. 37883.

Frederick, J. D. and Mary Jane Wilson, 1999, Editors, SPE Environmental Monograph Environmental Engineering for Exploration and Production Activities

Frederick, J. D. *Meter-based Cost impact of Energy and GHG Regulation and Operational Mitigation*, AEE Conference on Strategic Planning for Energy and the Environment, 2010

WZI INC.

Curriculum Vitae
Of
Jesse D. Frederick
WZI INC.

1717 28th Street Bakersfield, California 93301 (661) 326-1112 FAX: (661) 326-0191

ADJUDICATORY, JURY, SEMI-ADJUDICATORY PROCEEDINGS

Client	Case or Variance #	Type	Dates	
California Public Utility Commission	General Rate Case A10-03-014	Expert Witness	2010	
Garrison & McInnis	Chesser v. Alea	Expert: Energy Valuation and forecast 2010		2009
CA Dept. of Transportation	Cal Trans v 927 Indio Muerto	Expert: facility valuation	2008	
Klein DeNatale Goldner, et al.	Geisert v. Patterson, et al.	Expert, Energy Valuation	2007	
Gallagher and Gallagher	Moss v. Venoco	Litigation Support Benzene Tort, settled	2004	
Cooper & Hoppe	Kophamer v. Western Sky	Expert Testimony	2004	
El Paso Merchant Energy	CEC Docket 00-AFC-5	Expert: Power Plant Siting	2001	
Midway Sunset Cogeneration Company	CEC Docket 99-AFC-9	Expert: Power Plant Siting	2000-2001	
Southern California Gas Co.	The Gas Company v. Midsun Partners	Expert (CPUC) Property Valuation	1998-1999	
Noriega & Alexander	Tannehill v. Baker	Expert opinion Well Contamination	1997	
Klein, DeNatale, Goldner, Cooper, Rosenlieb and Kimball, LLP	World Oil	Confidential	1997-1998	
Guy E. Taylor & Associates	CIV-94-1529T	Expert opinion groundwater contamination source delineation oilfield operation.	1997	
Babst, Calland Clements and Zomir	U.S. DOJ/EPA v. Quaker State Congo Refinery	Expert: Refinery Contamination Litigation	1996	
Klein, DeNatale, Goldner, Cooper, Rosenlieb and Kimball, LLP	Tuytens et al	Expert: Facility Evaluation	1996	
Destec Energy, Inc.	CCN Docket 11000	Expert Testimony, Externalities Valuation	1993	

DEPOSITIONS

Client	Case or Variance #	Type	Dates
Garrison & McInnis 2008	Chesser v. Alea	Energy Price Forecast Insurance Claim	
CA Dept. of Transportation	Cal Trans v. 927 Indio Muerto	Condemnation of Chemical Facilities	2008
Klein, DeNatale, Goldner, Cooper Rosenlieb and Kimball, LLP	Tuytens et al. v. DifWind Farms VI	DifWind Farms VI Deposition Energy Contract Value	1997
Babst, Calland Clements	U.S. DOJ/EPA v. Quaker	Groundwater Contamination	1996

and Zomir	State Congo Refinery	Litigation

TESTIMONY – ADMINISTRATIVE HEARINGS

Client	**Case or Variance #**	**Type**	**Dates**
Castle & Cooke	Planning Commission	Vesting Tentative Tract Map 6281	2004
Castle & Cooke	Planning Commission	Vesting Tentative Tract Map 6250	2004
Castle & Cooke	Planning Commission	Panama & Ashe GPA/ZC	2004
Castle & Cooke	Planning Commission	Stockdale & Allen GPA/ZC	2004
Castle & Cooke	Planning Commission	Vesting Tentative Tract Map 11035	2004
Lucas Development	City Council	Vesting Tentative Tract Map 6182	2003
Sage Community Development	Planning Commission	Vesting Tentative Tract Map 6148	2003
Sage Community Development	City Council	Vesting Tentative Tract Map 6149	2003
White & H Partners	City Council	Vesting Tentative Tract Map 6137	2003
Vanderham Dairy	Board of Supervisors Planning Commission	EIR Appeal EIR	2003 2002
Borba Dairies	Board of Supervisors Planning Commission	EIR Appeal EIR	2002 2002
Badger Creek Limited	S-93-15	Interim Variance Regular Variance	1993 1993
Chalk Cliff Limited	93-20	Interim Variance Variance	1993 1993
Live Oak Limited	93-19	Regular Variance	1993
Chalk Cliff Limited	92-52	Interim Variance Regular Variance	1992 1992
Live Oak Limited	92-29	Interim Variance Regular Variance	1992 1992
	92-37	Interim Variance Regular Variance	1992 1992
San Joaquin Cogen Limited	92-05	Interim Variance Regular Variance	1992 1992
	92-06	Interim Variance Regular Variance	1992 1992
Badger Creek Limited	91-34	Interim Variance Regular Variance	1991 1991

Lube Oil Demister Exceedance

EXHIBIT "B"

The Practical Handbook
of
COMPOST
ENGINEERING

Roger T. Haug

The objectives of composting have traditionally been to biologically convert putrescible organics into a stabilized form and to destroy organisms pathogenic to humans. Composting is also capable of destroying plant diseases, weed seeds, insects, and insect eggs. Odor potential from compost is greatly reduced because organics that remain after proper composting are relatively stable with low rates of decomposition. Composting can also effect considerable drying, which has particular value with wet substrates such as municipal and industrial sludges. Decomposition of substrate organics together with drying during composting can reduce the cost of subsequent handling and increase the attractiveness of compost for reuse or disposal.

Organic composts can accomplish a number of beneficial purposes when applied to the land. First, compost can serve as a source of organic matter for maintaining or building supplies of soil humus, necessary for proper soil structure and moisture holding capacity. Second, compost can improve the growth and vigor of crops in commercial agriculture and home related uses. Stable compost can reduce plant pathogens and improve plant resistance to disease. Colonization by beneficial microorganisms during the latter stages of composting appears to be responsible for inducing disease suppression. Third, compost contains valuable nutrients including nitrogen, phosphorus, and a variety of essential trace elements. The nutrient content of compost is related to the quality of the original organic substrate. However, most composts are too low in nutrients to be classified as fertilizers. Their main use is as a soil conditioner, mulch, top dressing, or organic base with fertilizer amendments. On the other hand, nutrients such as nitrogen are organically bound and slowly released throughout the growing season, making them less susceptible to loss by leaching than soluble fertilizers.

Like the process of composting, there is no universal agreement of what makes something a compost. The following is a workable definition as used in this text. Compost is *an organic soil conditioner that has been stabilized to a humus-like product, that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and stored without nuisance, and that is beneficial to the growth of plants.*

ENGINEERING WITH MICROBES

The most common engineering application of microbes is to treat or convert substrates in aqueous solution. Suspended growth reactors, such as the activated sludge process, or fixed film reactors, such as the trickling filter, anaerobic filter, and rotating biological contactor, are widely used for treatment of municipal and industrial liquid wastes. Suspended cultures of microbes are used for fermentations to produce ethanol, antibiotics, and medicines. Biochemical engineering is well developed and it is possible to design and operate such systems using a reasoned, engineered approach.

There are a number of biological processes used on solid or semisolid materials including fermentation and ripening of cheese, production of silage, and, of course, composting. At least in the case of composting, a reasoned, fundamental approach to analysis and design of new facilities and operation of existing ones has not been fully developed. The first edition of this book, published in 1980, presented a "first generation" approach to biochemical engineering analysis of the process. This second edition continues the evolution and considerably advances the tools available for analysis compared to the first edition.

Almost every book on the subject of composting begins with the statement that composting is an ancient art, practiced by man since before the dawn of recorded history. Although the evidence does suggest that man has had a long affair with composting, fundamental scientific

ire of compounds of unknown composition. Open and
used experimentally to determine the heats of combus-
number of empirical equations are also available which
nd require only routine laboratory analysis.
. composting material can be treated as separate compo-
)int. The water fraction exhibits the thermal properties of
ie properties of the dry solid. This result is significant to
; presented in later chapters.

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:rmodynamics (Reading, MA: Addison-Wesley Publishing Co., Inc.,

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and Disposal of Wastewater Sludges, 2nd ed. (Ann Arbor, MI: An

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)75).

Chapter 4

Biological Fundamentals

INTRODUCTION

This chapter provides a brief introduction to the biology of organisms responsible for
composting, the bacteria and fungi. The discussion should acquaint the reader with sufficient
terminology to allow an understanding of the fundamental biology involved in composting.
It will not be a detailed discussion from the viewpoint of the microbiologist, but it will stress
the energy requirements and overall chemical reactions mediated by microbes.

The distinction of living things into plant and animal kingdoms is common to our experi-
ence. With the discovery of and experimentation with microorganisms, however, distinctions
became less well defined. Microbes seemed to have characteristics of both the plant and
animal kingdoms. In 1866 Ernst H. Haeckel, a German zoologist, proposed the kingdom
Protista which included bacteria, algae, protozoa, and fungi. All unicellular (single-celled)
organisms and those containing multiple cells of the same type are included in this classifi-
cation. Viruses, which are noncellular, were not discovered until 1882 and so escaped
Haeckel's original classification. For convenience, viruses are often included in the Protist
kingdom. A breakdown of the Protist kingdom into groupings convenient for our discussion
is presented in Figure 4.1.

Bacteria and blue-green algae are procaryotic cell types, while other protists and all
higher organisms are of the eucaryotic cell type. The distinction is based on differences
in cellular anatomy. Procaryotic cells contain a single DNA strand, the nuclear substance is
not enclosed within a distinct membrane, and nuclear division is less complex than in
eucaryotes. Procaryotes are thought to be more primitive organisms on the evolutionary scale.
Protists of importance in composting include bacteria and fungi. All other groups are of
little significance. It should be noted that some workers in composting include actinomycetes
as a group distinct from bacteria and fungi. There appears to be considerable
confusion on this point, because actinomycetes have been at times classified as bacteria, fungi,
or a separate phylogenetic line. Actinomycetes are filamentous in form like many of
the fungi, yet they have a procaryotic cell structure like the bacteria. As a class they are active
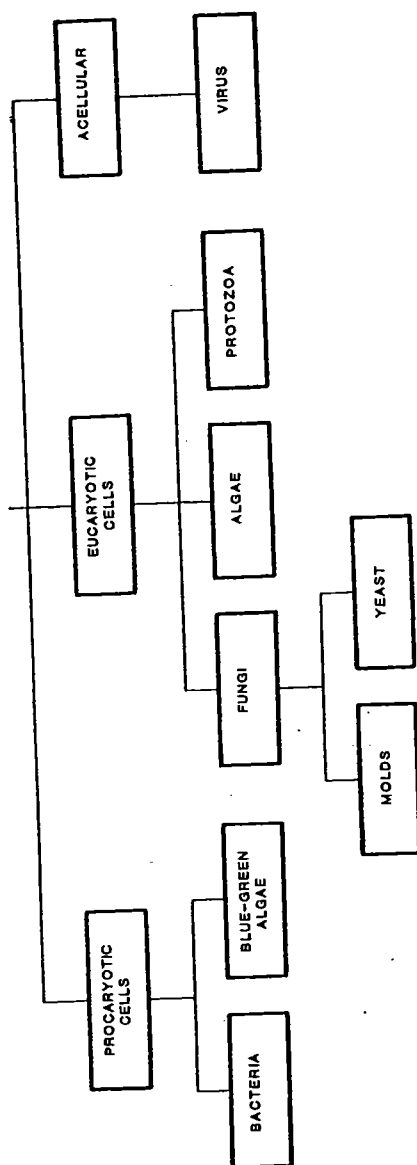
Figure 4.1.   Classification of microbes in the Protist kingdom.

in degradation of insoluble, high molecular weight organics, such as cellulose, chitin, proteins, waxes, paraffins, and rubber. As such, they should be important in composting systems. For convenience they will be considered along with bacteria, although the difficulty of classification should be recognized.
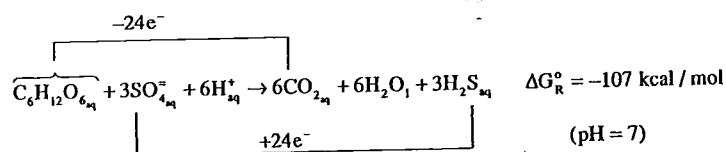
METABOLIC CLASSIFICATIONS

Metabolic distinctions between organisms provide a useful tool to understand both the effect of an organism on its surroundings and the environment necessary for proper growth of the organism. Perhaps the most basic distinction is between aerobic, anaerobic, and anoxic metabolism. Aerobic refers to respiration with oxygen. Consider the aerobic oxidation of glucose as follows:

$$\overline{C_6H_{12}O_{6_{aq}}} + 6O_{2_s} \rightarrow 6CO_{2_{aq}} + 6H_2O_l \qquad \Delta G_R^\circ = -677 \text{ kcal / mol}$$
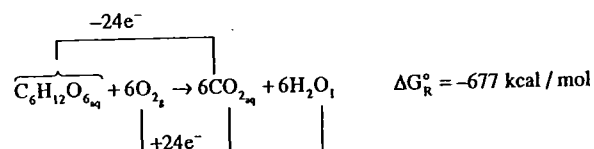
The reaction is of the oxidation-reduction type, because electrons are transferred from glucose and accepted by oxygen. Thus, oxygen is reduced while carbon is oxidized. In this case, oxygen is referred to as the electron acceptor. All organisms that use oxygen as an electron acceptor are termed aerobic. All macroscopic organisms, and many microscopic ones as well, are obligate aerobes. In other words, oxygen and only oxygen will serve as an electron acceptor.

Among the microbes, other compounds can be used as electron acceptors. The most notable of these are oxidized inorganic compounds of nitrogen and sulfur such as nitrate (NO_3^-), nitrite (NO_2^-), and sulfate (SO_4^{2-}). Carbon dioxide can also be used as an electron acceptor, and it is usually reduced to methane. Metabolism with these electron acceptors is termed anoxic. Many microbes can function with one or more of these electron acceptors and are termed facultative. The oxidation of glucose, using sulfate as an electron acceptor, is given as

$$\overline{C_6H_{12}O_{6_{aq}}} + 3SO_{4_{aq}}^= + 6H_{aq}^+ \rightarrow 6CO_{2_{aq}} + 6H_2O_l + 3H_2S_{aq} \qquad \Delta G_R^\circ = -107 \text{ kcal / mol}$$
$$(pH = 7)$$

Note that considerably less energy is available compared to aerobic metabolism. Being efficient chemical factories, microbes will first use those electron acceptors that provide the greatest energy yields. The order of use is generally O_2, NO_3^-, and SO_4^{2-}. This is fortunate, because production of H_2S can be prevented by maintenance of aerobic conditions.
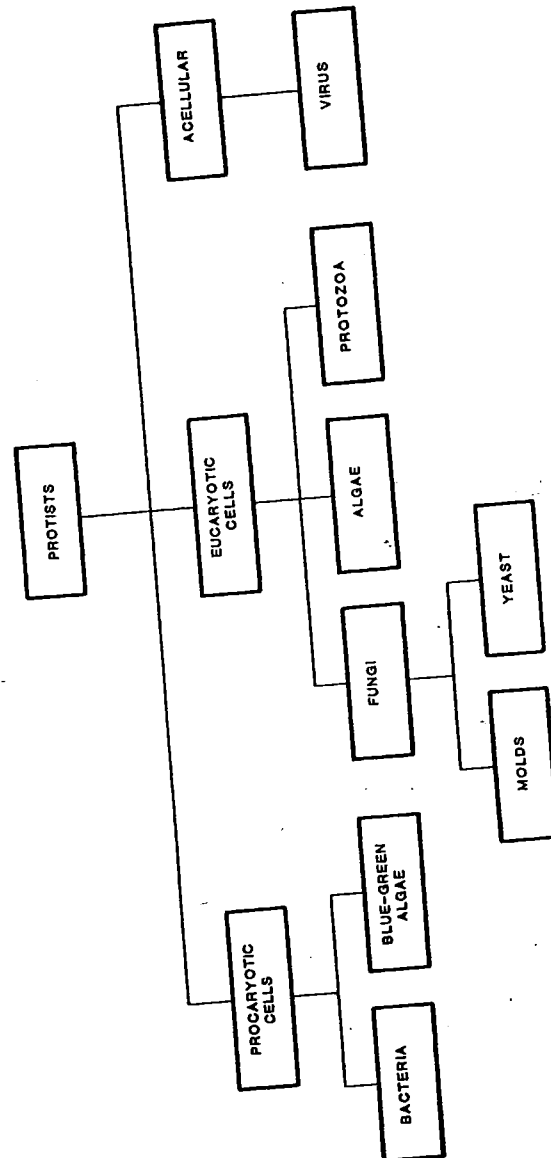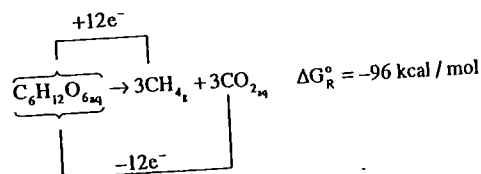
Figure 4.1. Classification of microbes in the Protist kingdom.

But what if all available electron acceptors have been used? Will electrons accumulate until the biochemical machinery grinds to a halt? The answer is no. To explain this consider the following reaction with glucose:

$$C_6H_{12}O_{6_{aq}} \rightarrow 3CH_{4_L} + 3CO_{2_{aq}} \qquad \Delta G_R^\circ = -96 \text{ kcal / mol}$$

with $+12e^-$ transferred in and $-12e^-$ transferred out.

Electrons removed from CO_2 are ultimately accepted by methane. Electrons are transferred and the reaction is of the oxidation-reduction type, but the acceptor and donor of electrons originate from the same molecule. Such reactions are termed fermentations, following Louis Pasteur who called fermentations "life without air". Some confusion in nomenclature still persists between different disciplines. Most industrial microbial conversions are called fermentations even though many of the processes are aerobic. Similarly, some composting reactors are called "fermenters" even though they usually take elaborate measures to assure aerobic conditions.

Anaerobic metabolism is considerably more complex than the above fermentation reaction with glucose would indicate. Conversions are frequently mediated by a variety of organisms operating in series. In other words, the product of one organism is used as substrate by the second organism, and so on. A variety of intermediate products can be formed along the way including low molecular weight organic acids (e.g., acetic and propionic), alcohols, and aldehydes. In sanitary engineering practice these organisms are collectively referred to as first stage or acid formers, although a variety of other intermediates can be formed. McCarty[1] has shown that with a complex starting substrate such as municipal sludges as much as 72% of the organics (measured as COD) pass through acetic acid. First-stage organisms are often important to industrial fermentation because of the end products formed. Ethanol is an obvious example of such an end product, resulting from the fermentation of sugars by selected yeast cultures.

If fermentation is allowed to go to completion, the final end products will always be methane and CO_2. At this point as much energy has been extracted from the substrate as possible under anaerobic conditions. Microbes that convert intermediate products to methane and CO_2 are termed methane-formers and are usually strict or obligate anaerobes.

The complexity of end products that result from anaerobic metabolism is often confusing to the student. Aerobic metabolism seems somewhat simpler because end products are basically carbon dioxide and water. In fact, the biochemical pathways are remarkably similar between the two groups. To help understand the reason for such variety of first stage end products, a number of possible reactions were assembled in Table 4.1. In all cases, the starting material is glucose and the flow of electrons is balanced. There is a rather large range of free energy values between the reactions listed. In a mixed microbial population, reactions yielding the most free energy predominate. Production of a single intermediate such as ethanol requires substrate preparation and pure or nearly pure cultures of selected microbes, which yield the desired end product.

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> a halt? The answer is no. To explain this consider the

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Table 4.1. Possible Anaerobic Fermentations of Glucose

End Products	Reactions	ΔG_R° @ pH =7 (kcal/mol glucose)
Acetate	$C_6H_{12}O_6 \rightarrow 3CH_3COO^- + 3H^+$	−78.55
Propionate, acetate, H_2	$C_6H_{12}O_6 \rightarrow CH_3CH_2COO^- + CH_3COO^- + 2H^+ + CO_2 + H_2$	−70.84
Butyric, H_2	$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + 2H_2$	−61.7
Ethanol	$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$	−51.14
Lactate	$C_6H_{12}O_6 \rightarrow 2CH_3CH(OH)COO^- + 2H^+$	−49.5
Methanol	$C_6H_{12}O_6 + 2H_2O \rightarrow 4CH_3OH + 2CO_2$	−21.42

Table 4.2. Metabolic Categories Based on Carbon and Energy Sources

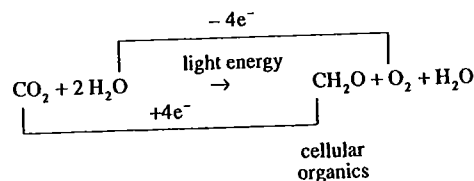| Types of Nutrition	Principal Source of Energy	Principal Source of Carbon	Occurrence
Photoautotroph	Light	CO_2	Some bacteria, most algae, higher plants
Photoheterotroph	Light	Organics	Some algae, some bacteria
Lithoautotroph (chemoautotroph)	Inorganic oxidation-reduction reactions	CO_2	Some bacteria
Organoheterotroph[a] (chemoheterotroph)	Organic oxidation-reduction reactions	Organics[b]	Higher animals, protozoa, fungi, and most bacteria

[a] In saprophytic nutrition, nonliving (inanimate) organic material is used; in parasitic or predatory nutrition, some or all of the materials used are animate.

[b] A few bacteria classified in this group are able to use CO_2 as a carbon source although this is not an energetically favorable pathway.

Metabolic classification of organisms can be continued by considering the carbon and energy sources used by the organism. Carbon accounts for about 50% of the dry mass of most organisms and is needed to synthesize the variety of organic molecules used in the structure and machinery of the cell. Two sources of carbon are available: carbon in the form of organic molecules, used by heterotrophs, and the carbon present in carbon dioxide, used by autotrophs.
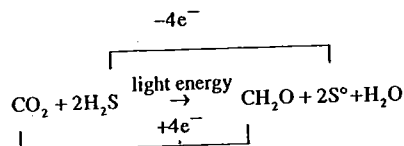
Three distinct energy sources are available to organisms: organic oxidation-reduction reactions, inorganic oxidation-reduction reactions, and the energy available in light. Organisms that use organic reactions for energy are termed organotrophs; those that use inorganic reactions are lithotrophs. Only bacteria are capable of using the energy of inorganic reactions. Organisms that use light for energy are phototrophs. By comparing the carbon and energy sources, four nutritional categories can be distinguished as shown in Table 4.2. One might suspect that with two carbon sources and three energy sources a total of six nutritional categories might be described. As far as it known today, however, all lithotrophs are also autotrophs. In other words, all lithotrophs obtain carbon from carbon dioxide. Likewise, all organotrophs will use organic carbon for synthesis. Therefore, the practical number of nutritional categories is reduced to four.

Although photoautotrophs are not significant to composting, this discussion of nutritional patterns would not be complete without a brief description of the pattern of electron flow for these organisms. Light is the ultimate source of energy for phototrophs. As such they do not depend on organic oxidation-reduction reactions in the same manner that organoheterotrophs do. However, electrons are still needed to reduce the cell carbon source, carbon dioxide, to the level needed for construction of organic molecules. These electrons are usually taken from the oxygen of water as indicated by the following simplified equation for photosynthesis:

$$\begin{array}{c} \overset{-\,4e^-}{\boxed{}} \\ CO_2 + 2\,H_2O \quad \overset{\text{light energy}}{\longrightarrow} \quad CH_2O + O_2 + H_2O \\ \underset{+4e^-}{\boxed{}} \\ \text{cellular} \\ \text{organics} \end{array}$$

Four electrons taken from oxygen in the water molecule are used to reduce the carbon dioxide. While simplified, this reaction is typical of the photosynthetic activity of algae and all higher plants.

Certain photosynthetic bacteria, notably the green and purple sulfur bacteria, are capable of extracting electrons from other sources such as sulfide, sulfur, H_2, and thiosulfate ($S_2O_3{}^{2-}$). A simplified equation representing the use of H_2S as an electron source is

$$\begin{array}{c} \overset{-4e^-}{\boxed{}} \\ CO_2 + 2H_2S \quad \overset{\text{light energy}}{\longrightarrow} \quad CH_2O + 2S^\circ + H_2O \\ \underset{+4e^-}{\boxed{}} \end{array}$$
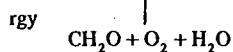
The reader might wonder why some bacteria are classified as photoautotrophs along with the algae and high plants. If bacteria are photosynthetic should they not then be called algae? The distinction centers on the type of chlorophyll contained in the cells. All algae, including the blue-green algae and all higher plants, contain the photosynthetic pigment chlorophyll-a, a particular type of chlorophyll, along with other light-sensitive pigments. Photosynthetic bacteria are procaryotic and do not contain chlorophyll-a. In addition, bacterial photosynthesis does not result in evolution of molecular oxygen, because electrons are obtained from sources other than water. Hence, a distinction is made between photosynthetic bacteria and all other photosynthetic organisms.

Now that these metabolic distinctions have been made, we are in a position to explore the types of reactions observed in the microbial world. Respiration using various reductants and oxidants is presented in Table 4.3. The reactions are indicative of those mediated by various groups of microbes. After studying Table 4.3 the reader should be sufficiently familiar with nutritional pathways to understand subsequent material.

BACTERIA

Bacteria are the smallest living organisms known. Bacteria are typically unicellular, but multicellular associations of individual cells are also common. They may exist in a number of morphological forms including spheres (cocci), rods (bacillus), spirals (spirillum), and a variety of intermediate forms such as comma-shaped (vibrio) and spindle-shaped (fusiform). Most bacteria reproduce by binary fission, division into two identical daughter cells. Sexual reproduction can also occur in certain cases.

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$$CH_2O + O_2 + H_2O$$

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organics

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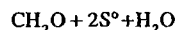
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Table 4.3.   General Types of Lithoautotrophic and Organoheterotrophic Metabolism

Reductant	Oxidant	Products	Carbon Source	Respiration	Metabolic Category	Type, Representative Organism
NH_4^+, NH_3	O_2	NO_2^-, H_2O	CO_2	Aerobic	Lithoautotroph	Nitrifying bacteria, *Nitrosomonas*
NO_2^-	O_2	NO_3^-	CO_2	Aerobic	Lithoautotroph	Nitrifying bacteria, *Nitrobacter*
S^{2-}, H_2S	O_2	SO_4^{2-}	CO_2	Aerobic	Lithoautotroph	Sulfur-oxidizing bacteria, *Thiobacillus, Thiothrix, Beggiatoa*
Fe^{2+}	O_2	Fe^{3+}, H_2O	CO_2	Aerobic	Lithoautotroph	Iron-oxidizing bacteria, *Ferrobacillus*
Fe^{2+}	NO_3^-	Fe^{3+}, N_2, H_2O	CO_2	Anoxic	Lithoautotroph	
H_2	O_2	H_2O	CO_2	Aerobic	Lithoautotroph	Hydrogen bacteria
H_2	CO_2	CH_4, H_2O	CO_2	Anaerobic	Lithoautotroph	CO_2-reducing bacteria, *Methanobacterium*
Organics	O_2	CO_2, H_2O	Organics	Aerobic	Organoheterotroph	Many bacteria
Organics	NO_3^-	CO_2, H_2O, N_2	Organics	Anoxic	Organoheterotroph	Denitrifying bacteria
Organics	SO_4^{2-}	CO_2, H_2O, H_2S	Organics	Anoxic	Organoheterotroph	Sulfur-reducing bacteria, *Desulfovibrio*
Organics	Organics	Many intermediates, see Table 4.1 $CH_4 + CO_2$ final products	Organics	Anaerobic	Organoheterotroph	Acid-forming bacteria, methane-forming bacteria

Table 7.1.   General Chemical Compositions for the Organic Fraction of Various Organic Materials

| Waste Component	Typical Chemical Composition	Reference
Carbohydrate	$(C_6H_{10}O_5)x$	
Protein	$C_{16}H_{24}O_5N_4$	
Fat and Oil	$C_{50}H_{90}O_6$	
Sludge		
Primary	$C_{22}H_{39}O_{10}N$	McCarty[1]
Combined	$C_{10}H_{19}O_3N$	Haug et al.[2]
Refuse (total organic fraction)	$C_{64}H_{104}O_{37}N$	Corey[3]
	$C_{99}H_{148}O_{59}N$	Corey[3]
	$C_{295}H_{420}O_{186}N$	Corey[3]
Wood	$C_{23}H_{38}O_{17}N$	Corey[3]
Grass	$C_{16}H_{27}O_8N$	
Garbage	$C_{18}H_{26}O_{10}N$	Kayhanian and Tchobanoglous[4]
Food wastes	$C_{266}H_{434}O_{210}N$	Kayhanian and Tchobanoglous[4]
Mixed paper	$C_{27}H_{38}O_{16}N$	Kayhanian and Tchobanoglous[4]
Yard wastes	$C_5H_7O_2N$	
Bacteria	$C_{10}H_{17}O_6N$	
Fungi		

cal compositions of various organics and organic mixtures are presented in Table 7.1. Using municipal sludge as an example and assuming an average composition from Table 7.1 of $C_{10}H_{19}O_3N$, the carbonaceous oxygen demand can be determined as

$$
\underset{201}{C_{10}H_{19}O_3N} + \underset{12.5\,(32)}{12.5\,O_2} \rightarrow 10\,CO_2 + 8\,H_2O + NH_3
$$
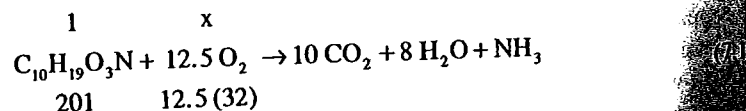
Based on the assumed substrate composition, the oxygen demand can be estimated as

$$x = 12.5(32)/201 = 1.99 \text{ g } O_2 \text{ g substrate BVS}$$

Ammonia released as a result of organic decomposition can be oxidized according to the following nitrification reaction:

$$
NH_3 + \underset{2(32)}{2O_2} \rightarrow NO_3^- + H_2O + H^+
$$
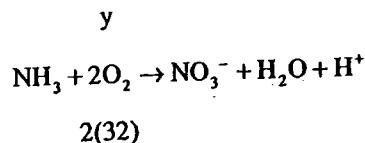
Assuming all ammonia is oxidized, the maximum nitrification demand for the substrate can be estimated as

$$y = 2(32)/201 = 0.32 \text{ g } O_2/\text{g substrate BVS}$$

The nitrification demand is significantly less than that required for organic oxidation. However, most of the produced ammonia will not be oxidized. Some will be used

EXHIBIT "C"

WASTEWATER ENGINEERING
Treatment, Disposal, and Reuse

Third Edition

METCALF & EDDY, INC.

Revised by

George Tchobanoglous

Professor of Civil Engineering
University of California, Davis

Franklin L. Burton

Vice President, Retired
Metcalf & Eddy, Inc.

sters and may upset the biological
g/L. Fortunately, such concentra-
d mixed with the wastewater gas
f burned in gas engines, the prod-
everely corrode exhaust-gas heat-
below the dew point.

ir toxicity, certain cations are of
wastewaters. Many of these com-
Table 3-9). Copper, lead, silver,
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le design of a biological treatment
duction of these ions to the extent
ent ceased. For instance, in sludge
00 mg/L, chromium and nickel are
l is also toxic at high concentrations
ammonium at 4000 mg/L. The alka-
ine with and precipitate the calcium
es the toxic level.
and chromates, are also present in
in metal-plating wastes and should
industry rather than be mixed with
toxic anion, is found commonly in
ilities. Organic compounds present in

etals, such as nickel (Ni), manganese
d), zinc (Zn), copper (Cu), iron (Fe),
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Table 3-9). Some of these metals are
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The presence of any of these metals in
y beneficial uses of the water because
desirable to measure and control the
s for determining the concentrations of
ng to the interfering substances that may
nany of these metals can be determined
ntal methods as polarography and atomic

water include nitrogen (N_2), oxygen (O_2)
$_2S$), ammonia (NH_3), and methane (CH_4)

The first three are common gases of the atmosphere and will be found in all waters exposed to air. The latter three are derived from the decomposition of the organic matter present in wastewater. Although not found in untreated wastewater, other gases with which the environmental engineer must be familiar include chlorine (Cl_2) and ozone (O_3) (disinfection and odor control), and the oxides of sulfur and nitrogen (combustion processes). The following discussion is limited to those gases that are of interest in untreated wastewater. Under most circumstances, the ammonia in untreated wastewater will be present as the ammonium ion (see "Nitrogen").

Dissolved Oxygen. Dissolved oxygen is required for the respiration of aerobic microorganisms as well as all other aerobic life forms. However, oxygen is only slightly soluble in water. The actual quantity of oxygen (other gases too) that can be present in solution is governed by (1) the solubility of the gas, (2) the partial pressure of the gas in the atmosphere, (3) the temperature, and (4) the purity (salinity, suspended solids, etc.) of the water. The interrelationship of these variables is delineated in Chap. 6 and is illustrated in Appendix E, where the effect of temperature and salinity on dissolved-oxygen concentration is presented.

Because the rate of biochemical reactions that use oxygen increases with increasing temperature, dissolved-oxygen levels tend to be more critical in the summer months. The problem is compounded in summer months because stream flows are usually lower, and thus the total quantity of oxygen available is also lower. The presence of dissolved oxygen in wastewater is desirable because it prevents the formation of noxious odors. The role of oxygen in wastewater treatment is discussed in Chaps. 9 and 10; its importance in water-quality management is discussed in Chap. 17.

Hydrogen Sulfide. Hydrogen sulfide is formed, as mentioned previously, from the anaerobic decomposition of organic matter containing sulfur or from the reduction of mineral sulfites and sulfates. It is not formed in the presence of an abundant supply of oxygen. This gas is a colorless, inflammable compound with the characteristic odor of rotten eggs. The blackening of wastewater and sludge usually results from the formation of hydrogen sulfide that has combined with the iron present to form ferrous sulfide (FeS). Various other metallic sulfides are also formed. Although hydrogen sulfide is the most important gas formed from the standpoint of odors, other volatile compounds such as indol, skatol, and mercaptans, which may also be formed during anaerobic decomposition, may cause odors far more offensive than that of hydrogen sulfide.

Methane. The principal by-product of the anaerobic decomposition of the organic matter in wastewater is methane gas (see Chaps. 8 and 12). Methane is a colorless, odorless, combustible hydrocarbon of high fuel value. Normally, large quantities are not encountered in untreated wastewater because even small amounts of oxygen tend to be toxic to the organisms responsible for the production of methane (see Chap. 8). Occasionally, however, as a result of anaerobic decay in accumulated bottom deposits, methane is produced. Because methane is highly combustible and

EXHIBIT "D"

Exhibit C_AB 341 Assembly Bill - CHAPTERED.txt
AB 341 CHAPTERED
        BILL TEXT

        CHAPTER 476
        FILED WITH SECRETARY OF STATE   OCTOBER 6, 2011
        APPROVED BY GOVERNOR   OCTOBER 5, 2011
        PASSED THE SENATE   SEPTEMBER 8, 2011
        PASSED THE ASSEMBLY   SEPTEMBER 8, 2011
        AMENDED IN SENATE   SEPTEMBER 2, 2011
        AMENDED IN SENATE   AUGUST 30, 2011
        AMENDED IN SENATE   JULY 7, 2011
        AMENDED IN ASSEMBLY   MAY 5, 2011
        AMENDED IN ASSEMBLY   APRIL 6, 2011

INTRODUCED BY   Assembly Member Chesbro
    (Principal coauthor: Senator Padilla)
    (Coauthors: Assembly Members Blumenfield and Williams)

                    FEBRUARY 10, 2011

    An act to amend Sections 41730, 41731, 41734, 41735, 41736, 41800,
42926, 44004, and 50001 of, to add Sections 40004, 41734.5, and
41780.01 to, to add Chapter 12.8 (commencing with Section 42649) to
Part 3 of Division 30 of, and to add and repeal Section 41780.02 of,
the Public Resources Code, relating to solid waste.

        LEGISLATIVE COUNSEL'S DIGEST

    AB 341, Chesbro. Solid waste: diversion.
    (1) The California Integrated Waste Management Act of 1989, which
is administered by the Department of Resources Recycling and
Recovery, requires each city, county, and regional agency, if any, to
develop a source reduction and recycling element of an integrated
waste management plan containing specified components, including a
source reduction component, a recycling component, and a composting
component. With certain exceptions, the source reduction and
recycling element of that plan is required to divert 50% of all solid
waste from landfill disposal or transformation by January 1, 2000,
through source reduction, recycling, and composting activities. The
department is required to file an annual progress report with the
Legislature by March 1 that includes specified information regarding
the act.
    This bill would make a legislative declaration that it is the
policy goal of the state that not less than 75% of solid waste
generated be source reduced, recycled, or composted by the year 2020,
and would require the department, by January 1, 2014, to provide a
report to the Legislature that provides strategies to achieve that
policy goal and also includes other specified information and
recommendations. The bill would allow the department to provide the
report required by the bill in conjunction with the annual progress
report, if the combined report is submitted by January 1, 2014. The
bill would repeal the report requirement on January 1, 2017.
    (2) Existing law requires a city, county, and city and county to
incorporate the nondisposal facility element and any amendment to the
element into the revised source reduction and recycling element at
the time of the 5-year revision of the source reduction and recycling
element. Existing law requires the department to review an amendment
to a nondisposal facility element and requires a local task force to
review and comment on amendments to a nondisposal facility element.
    This bill would repeal those requirements. The bill would instead
require a city, county, city and county, or regional agency to update
                            Page 1

Exhibit C_AB 341 Assembly Bill - CHAPTERED.txt
all information required to be included in the nondisposal facility
element. The bill would provide that the update is not subject to
approval by the department or comment and review by a local task
force.
    (3) Existing law requires a local agency to impose certain
requirements on an operator of a large venue or event to facilitate
solid waste reduction, reuse, and recycling.
    This bill would require a business, defined to include a
commercial or public entity, that generates more than 4 cubic yards
of commercial solid waste per week or is a multifamily residential
dwelling of 5 units or more to arrange for recycling services, on and
after July 1, 2012.
    The bill would also require a commercial waste generator to take
specified actions with regard to recyclable materials.
    The bill would require a jurisdiction, on and after July 1, 2012,
to implement a commercial solid waste recycling program meeting
specified elements but would not require the jurisdiction to revise
its source reduction and recycling element if the jurisdiction adds
or expands a commercial solid waste recycling program to meet this
requirement. The bill would authorize a local agency to charge and
collect a fee from a commercial waste generator to recover the local
agency's costs incurred in complying with the commercial solid waste
recycling program requirements. By requiring a jurisdiction to
implement a commercial solid waste recycling program, this bill would
impose a state-mandated local program.
    The bill would require the department to review a jurisdiction's
compliance with the above requirement as a part of the department's
review of a jurisdiction's compliance with the 50% solid waste
diversion requirement and would authorize the department to review a
jurisdiction's compliance pursuant to a specified procedure.
    (4) Existing law requires each state agency to submit an annual
report to the department summarizing its progress in reducing solid
waste that is due on September 1 of each year starting in 2009.
    This bill would change the due date to May 1 of each year.
    (5) Existing law requires an operator of a solid waste facility
that wants to change the design or operation of the solid waste
facility in a manner not authorized by the current permit to apply
for a revised permit. Within 60 days of receipt of the application
for the revised permit, the enforcement agency is required to inform
the operator, and in some circumstances the department, of its
determination to allow the change without revision of the permit,
disallow the change, require a revision of the permit to allow the
change, or require review under the California Environmental Quality
Act before a decision is made.
    This bill would also require the enforcement agency to give notice
of its determination to allow certain changes without a revision to
the permit through a modification to the permit allowed by
regulations developed by the department.
    (6) The California Constitution requires the state to reimburse
local agencies and school districts for certain costs mandated by the
state. Statutory provisions establish procedures for making that
reimbursement.
    This bill would provide that no reimbursement is required by this
act for a specified reason.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

    SECTION 1.   (a) The Legislature finds and declares both of the
following:
    (1) Since the enactment of the California Integrated Waste
Management Act of 1989 (Division 30 (commencing with Section 40000)
of the Public Resources Code), local governments and private

Exhibit C_AB 341 Assembly Bill - CHAPTERED.txt
industries have worked jointly to create an extensive material
collection and recycling infrastructure and have implemented
effective programs to achieve a statewide diversion rate above 50
percent.

(2) Although the state now leads the nation in solid waste
reduction and recycling, the state continues to dispose of more than
40 million tons of solid waste each year, which is more than the
national average on a per capita basis. Additional efforts must be
undertaken to divert more solid waste from disposal in order to
conserve scarce natural resources.

(b) The Legislature further finds and declares all of the
following:

(1) Approximately 64 percent of the state's solid waste disposal
is from commercial sources, including commercial, industrial,
construction, and demolition activities. In addition, 8 percent of
the state's solid waste disposal is from multifamily residential
housing that is often collected along with the commercial waste
stream.

(2) The state's local governments have made significant progress
in reducing the amount of solid waste disposal from single-family
residential sources that make up 28 percent of the state's disposal,
but have faced more challenges in reducing disposal from the
commercial and multifamily sources.

(3) The disposal of recyclable materials in the commercial solid
waste stream prevents materials from circulating in the state economy
to produce jobs and new products. Reducing the disposal of these
materials will conserve landfill capacity and contribute to a
reduction in greenhouse gas emissions and climate change.

(4) The state has long been a national and international leader in
environmental stewardship efforts and mandating the diversion of
solid waste away from disposal. Bold environmental leadership and a
new approach are needed to divert commercial solid waste away from
disposal.

(5) By exercising a leadership role, the state will lead the
business community toward a future in which the environment and the
economy both grow stronger together by recycling materials, which
creates new jobs, instead of burying resources, which exit the
economy forever.

(6) By requiring commercial recycling, the state will help
businesses reduce costly disposal fees and reclaim valuable
resources.

SEC. 2.   Section 40004 is added to the Public Resources Code, to
read:

40004.   (a) The Legislature finds and declares all of the
following:

(1) Solid waste diversion and disposal reduction require the
availability of adequate solid waste processing and composting
capacity.

(2) The existing network of public and private solid waste
processing and composting facilities provides a net environmental
benefit to the communities served, and represents a valuable asset
and resource of this state, one that must be sustained and expanded
to provide the additional solid waste processing capacity that will
be required to achieve the additional solid waste diversion targets
expressed in Section 41780.01 and the commercial solid waste
recycling requirement expressed in Section 42649.

(3) The provisions in existing law that confer broad discretion on
local agencies to determine aspects of solid waste handling that are
of local concern have significantly contributed to the statewide
diversion rate exceeding 50 percent, and further progress toward
decreasing solid waste disposal requires that this essential element
of local control be preserved.

(b) It is the intent of the Legislature to encourage the

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development of the additional solid waste processing and composting capacity that is needed to meet state objectives for decreasing solid waste disposal by identifying incentives for local governments to locate and approve new or expanded facilities that meet and exceed their capacity needs, and to recognize local agencies that make significant contributions to the state's overall solid waste reduction and recycling objectives through the siting of facilities for the processing and composting of materials diverted from the solid waste stream.

(c) By setting new commercial solid waste recycling requirements in Section 42649, the Legislature does not intend to limit a right afforded to local governments pursuant to Section 40059, or to modify or abrogate in any manner the rights of a local government or solid waste enterprise with regard to a solid waste handling franchise or contract.

SEC. 3. Section 41730 of the Public Resources Code is amended to read:

41730. Except as provided in Section 41750.1, each city shall prepare, adopt, and, except for a city and county, transmit to the county in which the city is located a nondisposal facility element that includes all of the information required by this chapter and that is consistent with the implementation of a city source reduction and recycling element adopted pursuant to this part. The nondisposal facility element and any updates to the element shall not be subject to the approval of the county and the majority of cities with the majority of the population in the incorporated area.

SEC. 4. Section 41731 of the Public Resources Code is amended to read:

41731. Except as provided in Section 41750.1, each county shall prepare, adopt, and, except for a city and county, transmit to the cities located in the county a nondisposal facility element that includes all of the information required by this chapter and that is consistent with the implementation of a county source reduction and recycling element adopted pursuant to this part. The nondisposal facility element and any updates to the element shall not be subject to the approval of the majority of cities with the majority of the population in the incorporated area.

SEC. 5. Section 41734 of the Public Resources Code is amended to read:

41734. (a) (1) Prior to adopting a nondisposal facility element, the city, county, or regional agency shall submit the element to the task force created pursuant to Section 40950 for review and comment.

(2) Prior to adopting a regional agency nondisposal facility element, if the jurisdiction of the regional agency extends beyond the boundaries of a single county, the regional agency shall submit the element for review and comment to each task force created pursuant to Section 40950 of each county within the jurisdiction of the regional agency.

(b) Comments by the task force shall include an assessment of the regional impacts of potential diversion facilities and shall be submitted to the city, county, or regional agency and to the department within 90 days of the date of receipt of the nondisposal facility element for review and comment.

SEC. 6. Section 41734.5 is added to the Public Resources Code, to read:

41734.5. (a) Once a nondisposal facility element has been adopted, the city, county, or regional agency shall update all information required to be included in the nondisposal facility element, including, but not limited to, new information regarding existing and new, or proposed, nondisposal facilities.

(b) Updates shall be provided to the department within 30 days of any change in information.

(c) Copies of the updated information shall also be provided to

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the local task force and shall be appended or otherwise added to the nondisposal facility element.

(d) The local task force shall not be required to review and comment on the updates to the nondisposal facility elements.

(e) Updates to the nondisposal facility elements are not subject to approval by the department.

SEC. 7. Section 41735 of the Public Resources Code is amended to read:

41735. (a) Notwithstanding Division 13 (commencing with Section 21000), the adoption or update of a nondisposal facility element shall not be subject to environmental review.

(b) Local agencies may impose a fee on project proponents to fund their necessary and actual costs of preparing and approving updates to nondisposal facility elements.

SEC. 8. Section 41736 of the Public Resources Code is amended to read:

41736. It is not the intent of the Legislature to require cities and counties to revise their source reduction and recycling elements to comply with the requirements of this chapter.

SEC. 9. Section 41780.01 is added to the Public Resources Code, to read:

41780.01. (a) The Legislature hereby declares that it is the policy goal of the state that not less than 75 percent of solid waste generated be source reduced, recycled, or composted by the year 2020, and annually thereafter.

(b) Notwithstanding subdivision (a), the department shall not establish or enforce a diversion rate on a city or county that is greater than the 50 percent diversion rate established pursuant to Section 41780.

SEC. 10. Section 41780.02 is added to the Public Resources Code, to read:

41780.02. (a) On or before January 1, 2014, the department shall submit a report to the Legislature that provides strategies to achieve the state's policy goal that not less than 75 percent of solid waste generated be source reduced, recycled, or composted by the year 2020, and annually thereafter, pursuant to Section 41780.01.

(b) The report shall also include all of the following:

(1) A review and update of the information required pursuant to subparagraph (A) of paragraph (4) of subdivision (c) of Section 40507, with emphasis on new and emerging trends in resource management.

(2) Identification of problematic waste streams and sources and recommendations on handling those waste streams.

(3) Evaluation of current programs and their effectiveness, and recommendations for changes to those programs.

(4) Recommendations for reprioritizing existing resources to best achieve the purpose of Section 41780.01.

(5) Recommendations for legislative changes, if any, that are necessary to achieve the goals of Section 41780.01.

(6) Report on regulatory changes, if any, that are necessary, to achieve the goals of Section 41780.01.

(7) Any other information or recommendations the department deems pertinent.

(c) The department may provide the report required pursuant to this section in conjunction with the report required pursuant to Section 40507 if the combined report is submitted on or before January 1, 2014.

(d) The department may hold public workshops to gather input from stakeholders.

(e) (1) Pursuant to Section 10231.5 of the Government Code, this section is repealed on January 1, 2017.

(2) The report shall be submitted in compliance with Section 9795

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of the Government Code.
   SEC. 11.   Section 41800 of the Public Resources Code is amended to
read:
   41800.   (a) Except as provided in subdivision (b), within 120 days
from the date of receipt of a countywide or regional integrated
waste management plan that the department has determined to be
complete, or any element of the plan that the department has
determined to be complete, the department shall determine whether the
plan or element is in compliance with Article 2 (commencing with
Section 40050) of Chapter 1 of Part 1, Chapter 2 (commencing with
Section 41000), and Chapter 5 (commencing with Section 41750), and,
based upon that determination, the department shall approve,
conditionally approve, or disapprove the plan or element.
   (b) (1) Within 120 days from the date of receipt of a city,
county, or regional agency nondisposal facility element that the
department has determined to be complete, the department shall
determine whether the element that the department has determined to
be complete is in compliance with Chapter 4.5 (commencing with
Section 41730) and Article 1 (commencing with Section 41780) of
Chapter 6, and, based upon that determination, the department shall
approve, conditionally approve, or disapprove the element within that
time period.
   (2) In reviewing the element, the department shall:
   (A) Not consider the estimated capacity of the facility or
facilities in the element unless the department determines that this
information is needed to determine whether the element meets the
requirements of Article 1 (commencing with Section 41780) of Chapter
6.
   (B) Recognize that individual facilities represent portions of
local plans or programs that are designed to achieve the diversion
requirements of Section 41780 and therefore may not arbitrarily
require new or expanded diversion at proposed facilities.
   (C) Not disapprove an element that includes a transfer station or
other facility solely because the facility does not contribute toward
the jurisdiction's efforts to comply with Section 41780.
   (c) If the department does not act to approve, conditionally
approve, or disapprove an element that the department has determined
to be complete within 120 days, the department shall be deemed to
have approved the element.
   SEC. 12.   Chapter 12.8 (commencing with Section 42649) is added to
Part 3 of Division 30 of the Public Resources Code, to read:
      CHAPTER 12.8.   RECYCLING OF COMMERCIAL SOLID WASTE

   42649.   (a) It is the intent of the Legislature to require
businesses to recycle solid waste that they generate.
   (b) It is the intent of the Legislature to allow jurisdictions
flexibility in developing and maintaining commercial solid waste
recycling programs.
   (c) It is the intent of the Legislature to reduce greenhouse gas
emissions by diverting commercial solid waste to recycling efforts
and to expand the opportunity for additional recycling services and
recycling manufacturing facilities in California.
   42649.1.   For purposes of this chapter, the following terms mean
the following:
   (a) "Business" means a commercial or public entity, including, but
not limited to, a firm, partnership, proprietorship, joint stock
company, corporation, or association that is organized as a
for-profit or nonprofit entity, or a multifamily residential
dwelling.
   (b) "Commercial solid waste" has the same meaning as defined in
Section 17225.12 of Title 14 of the California Code of Regulations.
   (c) "Commercial waste generator" means a business subject to

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subdivision (a) of Section 42649.2.

(d) "Self-hauler" means a business that hauls its own waste rather than contracting for that service.

42649.2. (a) On and after July 1, 2012, a business that generates more than four cubic yards of commercial solid waste per week or is a multifamily residential dwelling of five units or more shall arrange for recycling services, consistent with state or local laws or requirements, including a local ordinance or agreement, applicable to the collection, handling, or recycling of solid waste, to the extent that these services are offered and reasonably available from a local service provider.

(b) A commercial waste generator shall take at least one of the following actions:

(1) Source separate recyclable materials from solid waste and subscribe to a basic level of recycling service that includes collection, self-hauling, or other arrangements for the pickup of the recyclable materials.

(2) Subscribe to a recycling service that may include mixed waste processing that yields diversion results comparable to source separation.

(c) A property owner of a multifamily residential dwelling may require tenants to source separate their recyclable materials to aid in compliance with this section.

42649.3. (a) On and after July 1, 2012, each jurisdiction shall implement a commercial solid waste recycling program appropriate for that jurisdiction designed to divert commercial solid waste from businesses subject to Section 426492, whether or not the jurisdiction has met the requirements of Section 41780.

(b) If a jurisdiction already has a commercial solid waste recycling program as one of its diversion elements that meets the requirements of this section, it shall not be required to implement a new or expanded commercial solid waste recycling program.

(c) The commercial solid waste recycling program shall be directed at a commercial waste generator, as defined in subdivision (b) of Section 42649.1, and may include, but is not limited to, any of the following:

(1) Implementing a mandatory commercial solid waste recycling policy or ordinance.

(2) Requiring a mandatory commercial solid waste recycling program through a franchise contract or agreement.

(3) Requiring all commercial solid waste to go through either a source separated or mixed processing system that diverts material from disposal.

(d) The commercial solid waste recycling program shall include education, outreach to, and monitoring of, businesses. A jurisdiction shall notify a business if the business is not in compliance with Section 42649.2.

(e) The commercial solid waste recycling program may include enforcement provisions that are consistent with a jurisdiction's authority, including a structure for fines and penalties.

(f) The commercial solid waste recycling program may include certification requirements for self-haulers.

(g) The department shall review a jurisdiction's compliance with this section as part of the department's review required by Section 41825. Each jurisdiction shall report the progress achieved in implementing its commercial recycling program, including education, outreach, identification, and monitoring, and if applicable, enforcement efforts, by providing updates in the annual report required by Section 41821.

(h) The department may also review whether a jurisdiction is in compliance with this section at any time that the department receives information that a jurisdiction has not implemented, or is not making a good faith effort to implement, a commercial recycling

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program.

(i) During its review pursuant to subdivision (g) or (h), the department shall determine whether each jurisdiction has made a good faith effort to implement its selected commercial recycling program. For purposes of this section, "good faith effort" means all reasonable and feasible efforts by a jurisdiction to implement its commercial recycling program. During its review, the department may include, but is not limited to, the following factors in its evaluation of a jurisdiction's good faith effort:

(1) The extent to which businesses have complied with Section 42649.2, including information on the amount of disposal that is being diverted from the businesses, if available, and on the number of businesses that are subscribing to service.

(2) The recovery rate of the commercial waste from the material recovery facilities that are utilized by the businesses, all information, methods, and calculations, and any additional performance data, as requested by the department from the material recovery facilities pursuant to Section 18809.4 of Title 14 of the California Code of Regulations.

(3) The extent to which the jurisdiction is conducting education and outreach to businesses.

(4) The extent to which the jurisdiction is monitoring businesses, and notifying those businesses that are out of compliance.

(5) The availability of markets for collected recyclables.

(6) Budgetary constraints.

(7) In the case of a rural jurisdiction, the effects of small geographic size, low population density, or distance to markets.

42649.4. (a) If a jurisdiction adds or expands a commercial solid waste recycling program to meet the requirements of Section 42649.3, the jurisdiction shall not be required to revise its source reduction and recycling element, or obtain the department's approval pursuant to Article 1 (commencing with Section 41800) of Chapter 7 of Part 1.

(b) If an addition or expansion of a jurisdiction's commercial solid waste recycling program is necessary, the jurisdiction shall update in its annual report required pursuant to Section 41821.

42649.5. (a) This chapter does not limit the authority of a local agency to adopt, implement, or enforce a local commercial solid waste recycling requirement that is more stringent or comprehensive than the requirements of this section or limit the authority of a local agency in a county with a population of less than 200,000 to require commercial solid waste recycling.

(b) This chapter does not modify, limit, or abrogate in any manner any of the following:

(1) A franchise granted or extended by a city, county, or other local government agency.

(2) A contract, license, or permit to collect solid waste previously granted or extended by a city, county, or other local government agency.

(3) The existing right of a business to sell or donate its recyclable materials.

42649.6. A local agency may charge and collect a fee from a commercial waste generator in order to recover the local agency's costs incurred in complying with this chapter.

42649.7. If the State Air Resources Board adopts regulations for commercial recycling prior to the effective date of the act of the 2011-12 Regular Session of the Legislature adding this section, those regulations shall be deemed to have been adopted by the department, and they shall be added to the department's regulations and deleted from the board's regulations as if it were a change without regulatory effect.

SEC. 13. Section 42926 of the Public Resources Code is amended to read:

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42926.   (a) In addition to the information provided to the
department pursuant to Section 12167.1 of the Public Contract Code,
each state agency shall submit an annual report to the department
summarizing its progress in reducing solid waste as required by
Section 42921. The annual report shall be due on or before May 1,
2012, and on or before May 1 in each subsequent year. The information
in this report shall encompass the previous calendar year.
   (b) Each state agency's annual report to the department shall, at
a minimum, include all of the following:
   (1) Calculations of annual disposal reduction.
   (2) Information on the changes in waste generated or disposed of
due to increases or decreases in employees, economics, or other
factors.
   (3) A summary of progress made in implementing the integrated
waste management plan.
   (4) The extent to which the state agency intends to utilize
programs or facilities established by the local agency for the
handling, diversion, and disposal of solid waste. If the state agency
does not intend to utilize those established programs or facilities,
the state agency shall identify sufficient disposal capacity for
solid waste that is not source reduced, recycled, or composted.
   (5) Other information relevant to compliance with Section 42921.
   (c) The department shall use, but is not limited to the use of,
the annual report in the determination of whether the agency's
integrated waste management plan needs to be revised.
   SEC. 14.   Section 44004 of the Public Resources Code is amended to
read:
   44004.   (a) An operator of a solid waste facility shall not make a
significant change in the design or operation of the solid waste
facility that is not authorized by the existing permit, unless the
change is approved by the enforcement agency, the change conforms
with this division and all regulations adopted pursuant to this
division, and the terms and conditions of the solid waste facilities
permit are revised to reflect the change.
   (b) If the operator wishes to change the design or operation of
the solid waste facility in a manner that is not authorized by the
existing permit, the operator shall file an application for revision
of the existing solid waste facilities permit with the enforcement
agency. The application shall be filed at least 180 days in advance
of the date when the proposed modification is to take place unless
the 180-day time period is waived by the enforcement agency.
   (c) The enforcement agency shall review the application to
determine all of the following:
   (1) Whether the change conforms with this division and all
regulations adopted pursuant to this division.
   (2) Whether the change requires review pursuant to Division 13
(commencing with Section 21000).
   (d) Within 60 days from the date of the receipt of the application
for a revised permit, the enforcement agency shall inform the
operator, and if the enforcement agency is a local enforcement
agency, also inform the department, of its determination to do any of
the following:
   (1) Allow the change without a revision to the permit.
   (2) Allow the following changes without a revision to the permit
through a modification to the permit allowed pursuant to regulations
developed by the department:
   (A) The proposed change is to allow a nondisposal facility to
increase the amount of solid waste that it may handle and that
increased amount is within the existing design capacity as described
in the facility's transfer processing report and review pursuant to
Division 13 (commencing with Section 21000).
   (B) The proposed change is to allow a disposal facility to add a
nondisposal activity to the facility that will increase the amount of

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solid waste that may be handled as described in the facility's
report of facility information and review pursuant to Division 13
(commencing with Section 21000).
    (3) Disallow the change because it does not conform with the
requirements of this division or the regulations adopted pursuant to
this division.
    (4) Require a revision of the solid waste facilities permit to
allow the change.
    (5) Require review under Division 13 (commencing with Section
21000) before a decision is made.
    (e) The operator has 30 days within which to appeal the decision
of the enforcement agency to the hearing panel, as authorized
pursuant to Article 2 (commencing with Section 44305) of Chapter 4.
The enforcement agency shall provide notice of a hearing held
pursuant to this subdivision in the same manner as notice is provided
pursuant to subdivision (h).
    (f) Under circumstances that present an immediate danger to the
public health and safety or to the environment, as determined by the
enforcement agency, the 180-day filing period may be waived.
    (g) (1) A permit revision is not required for the temporary
suspension of activities at a solid waste facility if the suspension
meets either of the following criteria:
    (A) The suspension is for the maintenance or minor modifications
to a solid waste unit or to solid waste management equipment.
    (B) The suspension is for temporarily ceasing the receipt of solid
waste at a solid waste management facility and the owner or operator
is in compliance with all other applicable terms and conditions of
the solid waste facilities permit and minimum standards adopted by
the department.
                                      (2) An
owner or operator of a solid waste facility who temporarily suspends
operations shall remain subject to the closure and postclosure
maintenance requirements of this division and to all other
requirements imposed by federal law pertaining to the operation of a
solid waste facility.
    (3) The enforcement agency may impose any reasonable conditions
relating to the maintenance of the solid waste facility,
environmental monitoring, and periodic reporting during the period of
temporary suspension. The department may also impose any reasonable
conditions determined to be necessary to ensure compliance with
applicable state standards.
    (h) (1) (A) Before making its determination pursuant to
subdivision (d), the enforcement agency shall submit the proposed
determination to the department for comment and hold at least one
public hearing on the proposed determination. The enforcement agency
shall give notice of the hearing pursuant to Section 65091 of the
Government Code, except that the notice shall be provided to all
owners of real property within a distance other than 300 feet of the
real property that is the subject of the hearing, if specified in the
regulations adopted by the department pursuant to subdivision (i).
The enforcement agency shall also provide notice of the hearing to
the department when it submits the proposed determination to the
department.
    (B) The enforcement agency shall mail or deliver the notice
required pursuant to subparagraph (A) at least 10 days prior to the
date of the hearing to any person who has filed a written request for
the notice with a person designated by the enforcement agency to
receive these requests. The enforcement agency may charge a fee to
the requester in an amount that is reasonably related to the costs of
providing this service and the enforcement agency may require each
request to be annually renewed.
    (C) The enforcement agency shall consider environmental justice
issues when preparing and distributing the notice to ensure that the

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notice is concise and understandable for limited-English-speaking
populations.

(2) If the department comments pursuant to paragraph (1), the
department shall specify whether the proposed determination is
consistent with the regulation adopted pursuant to subdivision (i).

(i) (1) The department shall, to the extent resources are
available, adopt regulations that implement subdivision (h) and
define the term "significant change in the design or operation of the
solid waste facility that is not authorized by the existing permit."

(2) While formulating and adopting the regulations required
pursuant to paragraph (1), the department shall consider
recommendations of the Working Group on Environmental Justice and the
advisory group made pursuant to Sections 71113 and 71114 and the
report required pursuant to Section 71115.

SEC. 15. Section 50001 of the Public Resources Code is amended to
read:

50001. (a) Except as provided by subdivision (b), after a
countywide or regional agency integrated waste management plan has
been approved by the Department of Resources Recycling and Recovery
pursuant to Division 30 (commencing with Section 40000), a person
shall not establish or expand a solid waste facility, as defined in
Section 40194, in the county unless the solid waste facility meets
one of the following criteria:

(1) The solid waste facility is a disposal facility or a
transformation facility, the location of which is identified in the
countywide siting element or amendment to that element, which has
been approved pursuant to Section 41721.

(2) The solid waste facility is a facility that is designed to
recover for reuse or recycling at least 5 percent of the total volume
of material received by the facility, and that is identified in the
nondisposal facility element that has been approved pursuant to
Section 41800 or is included in an update to that element.

(b) Solid waste facilities other than those specified in
paragraphs (1) and (2) of subdivision (a) shall not be required to
comply with the requirements of this section.

(c) The person or agency proposing to establish a solid waste
facility shall prepare and submit a site identification and
description of the proposed facility to the task force established
pursuant to Section 40950. Within 90 days after the site
identification and description is submitted to the task force, the
task force shall meet and comment on the proposed solid waste
facility in writing. These comments shall include, but are not
limited to, the relationship between the proposed solid waste
facility and the implementation schedule requirements of Section
41780 and the regional impact of the facility. The task force shall
transmit these comments to the person or public agency proposing
establishment of the solid waste facility, to the county, and to all
cities within the county. The comments shall become part of the
official record of the proposed solid waste facility.

(d) The review and comment by the local task force shall not be
required for an update to a nondisposal facility element.

SEC. 16. No reimbursement is required by this act pursuant to
Section 6 of Article XIII B of the California Constitution because a
local agency or school district has the authority to levy service
charges, fees, or assessments sufficient to pay for the program or
level of service mandated by this act, within the meaning of Section
17556 of the Government Code.

EXHIBIT "E"

METHOD FOR ESTIMATING GREENHOUSE GAS EMISSION REDUCTIONS FROM COMPOST FROM COMMERCIAL ORGANIC WASTE

November 14, 2011

Planning and Technical Support Division

California Air Resources Board

California Environmental Protection Agency

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Method for Estimating Greenhouse Gas Emission Reductions from Compost from Commercial Organic Waste

EXECUTIVE SUMMARY

This document explains a life-cycle method to quantify the California-specific greenhouse gas emission reductions from using compost and the greenhouse gas emissions associated with compost management. Compost application to agricultural fields increases soil health while providing multiple co-benefits. Compost application reduces the amount of synthetic fertilizer needed, reduces the amount of water used, decreases soil erosion, increases soil carbon storage and reduces the use of herbicides. Composting material also causes greenhouse gas emissions during the collection of the initial feedstock and delivery of the compost, the use of energy and water to manage the compost pile, and as microorganisms convert the initial feedstock to compost. The following equation is used to calculate the compost emission reduction factor (CERF):

$$CERF = (CS_b + ((W_b + E_b + F_b + H_b) * C_{use})) - E_{total}$$

where,

$CERF$	=	Compost emission reduction factor ($MTCO_2E$/ton of feedstock)
CS_b	=	Emission reductions associated with the increased carbon storage in soil ($MTCO_2E$/ton of feedstock)
W_b	=	Emission reductions due to decreased water use ($MTCO_2E$/ton of compost)
E_b	=	Emission reduction associated with decreased soil erosion ($MTCO_2E$/ton of compost)
F_b	=	Factor to account for the reduced fertilizer use ($MTCO_2E$/ton of compost)
H_b	=	Factor to account for the reduced herbicide use ($MTCO_2E$/ton of compost)
C_{use}	=	Conversion factor used to convert from tons of compost to tons of feedstock
E_{total}	=	Emissions due to the composting process ($MTCO_2E$/ton of feedstock)

The above equation uses an approach similar to one established by the United Environmental Protection Agency (USEPA). This method modified USEPA's approach by quantifying the greenhouse gas composting benefits due to decreased fertilizer use, decreased water use, decreased soil erosion, and decreased herbicide use and by applying California-specific data where feasible. The CERF generated for this method is **0.42 MTCO$_2$E/ton of feedstock** (wet weight) and applies to food scraps, yard trimmings, grass, leaves, branches, and organic municipal solid waste (MSW).

1. BACKGROUND

In the past 17 years, the amount of organic waste composted in the United States has increased over 400 percent from about 4 to 20 million tons.[1] Composting is a decomposition process that converts an initial feedstock of organic waste (i.e. food scraps, yard trimmings, branches, leaves, grass, and organic municipal solid waste) into an organic-rich soil mixture called compost. Compost application to soil systems has many benefits, which include, but are not limited to, increased soil carbon concentrations, decreased density, increased porosity, increased resistance to erosion and pests, and decreasing the use of synthetic fertilizers.[2-7] In recent years, efforts have begun to quantify the above compost benefits in terms of greenhouse gas reductions.[8-12]

The quantification of greenhouse gas (GHG) emission reductions from compost application requires a life-cycle approach. A life-cycle approach accounts for emissions or emission reductions at the manufacturing, use or end-of-life stages for a single product.[13] Composting is unique because using its end-product reduces energy requirements in other products' life cycle stages. For example, applying compost can reduce the amount of water needed to irrigate a crop and thus the energy required to move the water to a particular field. It can also decrease the amount of industrially produced fertilizer. In the proposed method, the greenhouse gas (GHG) emission reductions are quantified with respect to the addition of compost as an amendment to an agricultural soil system. Additionally, emissions associated with the composting process, such as transportation, machinery use, and water use will be quantified.

This life-cycle method is consistent with other recent compost analyses in the literature. The United States Environmental Protection Agency (USEPA) Waste Reduction Model (WARM) quantifies the compost GHG benefit by accounting for the net emissions from the composting process and summing them with the benefit of soil carbon storage.[14] Studies by Martinez-Blanco et al (2009) and Blengini (2008) assess similar parameters as the WARM model, but also include fertilizer benefits.[15-16] However, these studies do not attempt to quantify the GHG benefits associated with a decline in water use, soil erosion and pesticide use, which may lead to a more conservative view of the benefits of compost.

This method evaluates the emission reduction benefits and emissions associated with the composting process and the agricultural use of its end-products. The emissions considered will be transportation (feedstock collection and delivery of finished product), process emissions (feedstock manipulation during the production of compost, including water use), and fugitive emissions (CH_4 and N_2O emissions from the composting material). The greenhouse gas emission benefits will include increased soil carbon storage, reduced soil erosion, reduced water use, and a decrease in fertilizer and herbicide use. Whenever feasible, studies from California composting operations and compost application will be used. The quantification of each of these variables will lead to a compost emission reduction factor (CERF) that will be applicable to food scraps, yard trimmings, grass, leaves, branches, and organic municipal solid waste (MSW).

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2. METHODS

The boundary,[17] or life-cycle stages used to quantify the compost emission reduction factor (CERF), for this method establishes the greenhouse gas emission reductions of compost application and greenhouse gas emissions from composting organic waste. This section describes the emissions from the composting process and secondly discusses the emission reductions associated with using compost as an agricultural amendment that were considered in this method. If compost is used as an agricultural amendment, all of the benefits discussed below are applicable. A survey completed by CalRecycle indicates that the majority (~ 75%) of compost application in California occurs for uses that would benefit from all of the variables discussed below (see section 2.2).[18] These include agricultural, landscape, and nursery applications.

2.1 Composting Emissions

There are three main emission sources that occur during the composting process: transportation emissions occurring from the collection of the initial feedstock and delivery of the finished compost; energy and water emissions from the composting management process; and fugitive emissions from the anaerobic decomposition of the composted materials. The significance of each emission is important because it detracts from the overall emission benefit of compost use. The emissions that are discussed in this method are consistent with the emissions in studies evaluating the GHG emissions from composting.[15,16,19] Biogenic carbon dioxide (CO_2) emissions from the degradation of organic material (i.e. branches and food scraps) during the composting process are not counted to maintain consistency with IPCC, USEPA, and ARB inventory accounting.[9,14] The overall emissions from composting are represented by the following equation:

$$E_{total} = T_e + P_e + F_e \qquad (1)$$

where,

E_{total} = Total emissions from composting (MTCO$_2$E/ton of feedstock)
T_e = Transportation emissions from composting (MTCO$_2$E/ton of feedstock)
P_e = Process emissions from composting (MTCO$_2$E/ton of feedstock)
F_e = Fugitive emissions from composting (MTCO$_2$E/ton of feedstock)

2.1.1 Transportation Emissions (T_e)

The transportation emissions (fossil fuel CO_2 emissions from diesel) associated with composting occurs during the collection of the organic feedstock to the composting facility and the delivery of the finished compost to the end user. The total distance travelled (inbound and outbound), in combination with an emission factor that indicates the amount of greenhouse gas emitted per distance travelled (g CO_2/ton·mile), gives an approximation of the emissions for transportation. The inbound and outbound distances vary across the state and depend on the

collection method and customer proximity to the composting facility. Discussions with CalRecycle staff led to the identification of six geographically representative compost facilities across the state.[20] Average transportations distances were obtained from a survey of Northern, Central and Southern California composters. The emission factor used was generated from Appendix G of the ARB's Statewide Truck and Bus Regulation (101 g CO_2/ton·mile).[21]

2.1.2 Process Emissions (P_e)

Process emissions from the composting process were from the energy required to grind material (electricity), turn and manage the compost pile (diesel) and the emissions associated with water use on the compost pile. California-specific data sources for this parameter were obtained from a personal communication with CalRecycle staff.[20]

2.1.3 Fugitive Emissions (F_e)

Fugitive emissions arise from methane (CH_4) and nitrous oxide (N_2O) releases during the composting process. Methane is produced in anaerobic pockets of a compost pile, while nitrous oxide is a product of nitrification or denitrification.[22] Even though the overall emissions of these two GHGs is low relative to carbon dioxide, their emissions are significant because their global warming potential (GWP) is 21 and 310 times greater than CO_2 for CH_4 and N_2O, respectively.[23] Numerous research articles discuss the release of CH_4 and N_2O emissions from composting. The list of studies include both manure[24-26] and organic waste[27-29] composting piles. However, manure is not normally contained in a commercial organic waste stream, so data from these studies were not used for this analysis. The values from the remaining papers that discussed CH_4 (n=7) and N_2O (n=4) emissions were averaged together.

2.2 Compost Emission Reductions

The greenhouse gas emission reduction benefits come from the agronomic use of compost and are calculated based on the finished compost product. The final reduction benefit is reported by converting the compost application benefit to units of initial organic feedstock. The addition of compost to soils produces many benefits that contribute to soil and plant health. While this analysis evaluates five benefits from a GHG perspective,[3] more benefits may occur from composting (such as increased crop yield), but existing data does not allow for their GHG quantification. The composting application benefits described in this method are listed in the equation below:

$$B_{total} = CS_b + ((W_b + E_b + F_b + H_b) * C_{use}) \qquad (2)$$

where

B_{total} = Total emission reduction benefit due to compost use (MTCO$_2$E/ton of feedstock)

CS_b = Emission reductions associated with the increased carbon storage

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		in soil ($MTCO_2E$/ton of feedstock)
W_b	=	Emission reductions due to decreased water use ($MTCO_2E$/ton of compost)
E_b	=	Emission reduction associated with decreased soil erosion ($MTCO_2E$/ton of compost)
F_b	=	Factor to account for the reduced fertilizer use ($MTCO_2E$/ton of compost)
H_b	=	Factor to account for the reduced herbicide use ($MTCO_2E$/ton of compost)
C_{use}	=	Conversion factor used to convert from tons of compost to tons of feedstock.

2.2.1 Increased Soil Carbon Storage (CS_b)

Compost increases the soil carbon content when it is applied to a soil with low concentrations of organic matter.[9,10,14] Over time, the reactive carbon content of the applied compost decreases due to plant and bacteria metabolism. The unreactive portion of carbon compounds, known as humic substances, remain in soil systems for long periods of time.[14] The carbon that remains in the soil system is considered stored because it is not degrading and releasing CO_2 into the atmosphere. Few studies have been completed that evaluate the impact of compost on soil carbon storage.[6,30,31] For this reason, a study from USEPA that evaluated soil carbon storage due to compost application was used to quantify the emission benefit in this method.[14] The USEPA study evaluated the soil carbon storage benefit from year 1 through year 30.[14]

2.2.2 Decreased Water Use (W_b)

Compost application decreases the density of soil due to an increase in soil porosity.[32-34] Increases in porosity and surface area creates more binding spots for water, leading to higher water retention rates when compared to an unamended soil.[33,34] The physical characteristics that allow for the increased water retention are directly due to the carbon content of the compost.[4] A decay pattern similar to carbon loss in compost was therefore used for modeling the water use benefits.[14]

A study conducted by the University of California – Riverside addresses the water retention benefits from compost application.[35] The data collected from this paper was converted into gallons saved/ton of compost and averaged. The average value was inputted into year 1 of the compost decay graph and plotted out to 30 years after compost application for consistency with carbon storage. The sum of water benefits was considered for this emission factor because every year a water benefit would be realized. The compost application benefit in this case is the reduced energy needed to transport water to the compost-amended soil. The emission factor for water use was 1.5 $MTCO_2E$ per acre-foot (AF).[36] This value is based on a statewide embedded energy in water value of 3.2 MWh/AF.[37]

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2.2.3 Decreased Soil Erosion (E_b)

When mixed into soil, compost has the ability to decrease erosion and is widely used as an erosion control device at construction sites, along highways and in agricultural applications.[4,32,38] Compost decreases erosion because of its ability to absorb and retain water in its pore holes. This method evaluated the erosion control benefits from agricultural applications. This benefit was quantified by accounting for the emissions associated with replacing eroded soil with compost. Erosion control is also related to carbon content, density and water retention so a decay pattern similar to carbon loss in compost was used for erosion control.

A study completed by the University of California-Riverside was used to evaluate the soil erosion.[35] This study evaluated two sites: a site damaged by a fire and a construction site. The construction site used seeded compost, but the researchers noted that there was no seed growth during the sampling events so the seeded compost mimicked unseeded compost.[35] An average erosion between the construction site and fire affected site was used in the calculation. The difference in soil retention between the control and compost-amended site was considered the soil benefit. The experimental plot values were extrapolated to represent a hectare of application and converted to a unit representative of soil saved per ton of compost. The emission factor for replacing one ton of eroded soil was 0.114 $MTCO_2E$/ton of feedstock (Section 3.1). The emission factor represents the emissions associated with producing compost to replace the soil lost to erosion.

2.2.4 Reduced Fertilizer Use (F_b)

The nitrogen content of compost, along with phosphorous and potassium contributions, provide an opportunity to reduce the amount of fertilizer applied to agricultural systems.[39-42] Other studies have shown that the use of compost does not entirely alleviate the need to apply fertilizers to agricultural soils.[43] The greenhouse gas benefit for this variable was quantified as the avoided synthetic nitrogen, potassium, and phosphorous production from compost use.

The nitrogen, potassium and phosphorous contents of fertilizer degrade more rapidly than carbon.[10] A study by Favoino and Hogg (2008) indicated that nitrogen from compost is used over a 10-year time period.[10] The study also assumed that nitrogen was "conserved" in the soil over time so the available nitrogen over a 10-year time period was actually greater than the initial nitrogen content.[10] Instead of assuming a 30% decay rate as Favoino and Hogg (2008),[10] this method used a value to 38% over a period of 10 years to ensure the nitrogen availability did not include the "conserved" nitrogen content. It was assumed that the decay of potassium and phosphorous were similar to nitrogen.

Data was obtained from an independent compost lab that tested nutrient and trace metal concentrations from compost in California.[44] The 10-year decay curve was applied to this data set. The emission factor used for each type fertilizer (N, P, or K) was based on the avoided life cycle emissions from fertilizer

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production that would have occurred in the absence of compost use. The emission factors for N, P, and K are 8.9, 1.8 and 0.96 kg CO_2E/kg, respectively.[9,45]

2.2.5 Reduced Herbicide Use (H_b)

Herbicide use in agricultural fields prevents weeds from growing in unwanted areas. Studies indicate that compost replaces the use of herbicide by forming a crust over the top of the soil, making it difficult for weeds to penetrate the surface.[46] These benefits are limited and may last only one year, but allow for the reduced use or alleviation of herbicide use.[47]

Reduced herbicide use was determined from a study from Roe et al (1993).[46] The herbicide benefit quantified by this study was multiplied by an emission factor for a pesticide (A life-cycle analysis was not available for a herbicide, so a pesticide was used as a proxy).[48] Other studies were found that dealt with reduced herbicide use and composting, but were not applicable because the data was not sufficiently quantitative.[49,50]

2.2.6 Conversion Factor (C_{use})

The composting benefits were quantified in terms of $MTCO_2E$ reduced per ton of applied compost. The conversion factor was used to convert from compost applied to original feedstock composted. This conversion factor is based on numerous studies that report the initial amount of feedstock composted and final amount of composted material.[9,16,28]

2.3 Compost Emission Reduction Factor (CERF)

The compost emission reduction factor (CERF) is the sum of compost process emissions (E_{total}) and compost application emission benefits (B_{total}):

$$CERF = B_{total} - E_{total} \qquad (3)$$

where,
CERF =   Compost emission reduction factor ($MTCO_2E$/ton of feedstock)
E_{total} =   Total emissions from the composting process ($MTCO_2E$/ton of feedstock)
B_{total} =   Total emission benefits due to the application of compost ($MTCO_2E$/ton of feedstock)

3. RESULTS AND DISCUSSION

This section presents the emissions from the composting process and the emission reduction benefits from applying compost to a non-amended soil. Included in this section will be an analysis of the sensitivity of these values in the context of determining an accurate CERF for use in California.

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3.1 Composting Emissions

Composting emissions are calculated in three different categories: emissions from transportation (inbound (collection) and outbound (delivery)), process emissions (turning, etc.) and fugitives (pile management). The calculated values are reported below.

3.1.1 Transportation Emissions (T_e)

Transportation emissions occur when the compost is collected (inbound) and when the finished product is distributed (outbound). Table 1 shows the location of composting facility and inbound and outbound transportation averages obtained from six representative compost distributors across the California.[20]

Table 1. Feedstock collection (inbound) and compost delivery (outbound) transportation distances.

Location	Inbound (miles)	Outbound (miles)
Oxnard	5	15
Rancho Cucamonga	30	30
San Jose	37	26
Northern California (various locations)	50	50
San Diego	108	N/A
Southern San Joaquin	55	20
Average	47.5	28.2
Sum	75.7	
Emissions	0.008 MTCO$_2$/ton	

The sum of the inbound and outbound travel miles was multiplied by an emission factor of 101 g CO$_2$/ton-mile.[21] The resulting average transportation emissions for the collection of feedstock and delivery of compost to the end user are **0.008 MTCO$_2$E/ton of feedstock**. Two European studies reported inbound distances of nine[15] and sixteen[16] miles. These values are slightly lower than the values used in this method and represent a 0.003 MTCO$_2$E/ton of feedstock deviation (on the lower side).

3.1.2 Process Emissions (P_e)

Composting is completed under varying conditions with specific physical parameters. Data from a Central Valley compost facility indicates that there is about 0.29 gallons of diesel and 250 gallons of water used per ton of initial feedstock for an outdoor windrow (Table 2).[20] The data reported in Table 2 represents the overall fuel and water use per ton of feedstock (activity column of Table 2). Each activity was multiplied by the corresponding emission factor. The water use emission factor is due to the embedded energy required to

transport water in the California.[36] The overall emission contributions were summed and averaged to obtain the final emission value (Table 2, last column).

Table 2. Process emissions from compost production.

Facility	Activity	Emission Factor	Emissions (MTCO$_2$E/ton of feedstock)[a]
Outdoor windrow #1			
	0.29 gal diesel/ton	10.2 kg CO$_2$E/gal[b]	0.003
	0.0008 AF/ton	1.5 MTCO$_2$E/AF[c,d]	0.001
Outdoor windrow #2			
	0.24 gal diesel/ton	10.2 kg CO$_2$E/gal[b]	0.002
Outdoor windrow #3			
	0.56 gal diesel/ton	10.2 kg CO$_2$E/gal[b]	0.006
	7.2 kWh/ton	0.419 kgCO$_2$E/kWh[e]	0.003
	0.0006 AF/ton	1.5 MTCO$_2$E/AF[c,d]	0.001
		Average	0.008

[a] In order to obtain the total value, an average for each process emission type was taken, when applicable. For example, the average diesel fuel use was taken between outdoor windrow samples 1-3 while, the electricity value from outdoor windrow 3 was only used. [b]Reference 51 [c] Reference 36; [d] AF=acre-foot. [e] Reference 51. Uses the 2007 California grid average electricity emission factor.

The values used for the process emissions in this method were compared to multiple studies completed in Europe.[9,15,16] These studies indicate that direct diesel emissions from shredders, front loaders, and turning equipment is generally in the range of 0.03 -1.4 gallon/ton of feedstock.[9] This range is consistent with the above diesel emissions shown in Table 2. The water emissions during the composting process ranged from 0.0002-0.00007 AF/ton of feedstock.[15,16] These values are low when compared to this method, but it should be noted that both of these studies evaluated indoor composting processes.[15,16]

3.1.3 Fugitive Emissions (F$_e$)

Fugitive CH$_4$ and N$_2$O emissions were compiled from various studies and averaged together for this method.[15,19,22,27-29,52] The majority of the studies were taken from a study completed by the Intergovernmental Panel on Climate Change (IPCC), but additional studies were added to take into account more recent data from green waste composting studies from Mediterranean climates (which are similar to California weather conditions).[15,29,53] Table 3 shows each study used generate the average for methane and nitrous oxide emissions from a compost pile.

Table 3. Fugitive CH₄ and N₂O emissions from composting.

CH₄	Reference	Feedstock	Emission factor (g_{CH4}/kg)
	Beck-Friis et al (2003)[a]	Household organics	3.6
	Beck-Friis et al (2000)[b]	Household organic mixed with coarsely chipped branches and bushes	11.9
	Hellmann et al (1997)[c]	Organic MSW with bush, leaves and grass clippings	0.172
	Hellebrand (1998)[d]	Green waste and grass	5.1
	Martinez-Blanco et al (2009)[e]	Organic MSW and pruning waste	0.38
	Amlinger et al (2008)[f]	Green waste, sewage sludge and biowaste	0.21
	Manios et al (2007)[g]	Mixture of olive branches, leaves, and mill sludge	7
		Average	**4.1**
			0.078 MTCO₂E/ton
N₂O			**(g_{N2O}/kg)**
	Beck-Friis et al (2000)[b]	Household organic mixed with coarsely chipped branches and bushes	0.1
	Hellmann et al (1997)[c]	Organic MSW with bush, leaves and grass clippings	0.022
	Hellebrand (1998)[d]	Green waste and grass	0.1
	Amlinger et al (2008)[f]	Green waste, sewage sludge and biowaste	0.13
		Average	**0.09**
			0.025 MTCO₂E/ton

[a] Reference 52; [b] Reference 22; [c] Reference 28; [d] Reference 27; [e] Reference 15; [f] Reference 19; [g] Reference 29

The values used in this method for fugitive methane and nitrous oxide emissions are consistent with other literature values. For example, the IPCC reports that

CH_4 emissions are 4 g CH_4/kg of compost and N_2O emissions are 0.3 g N_2O/kg of compost.[53] The N_2O value is slightly lower than the IPCC values and may be due to the feedstock types used in this method compared to the IPCC. When composting certain feedstock, such as manure, N_2O emissions were higher than this method.[24-26]

3.1.4 Summary of Emissions

Table 4 presents the total emissions (E_{total}) from the composting process.

Table 4. Summary of composting emissions (E_{total})

Emission type	Emission (MTCO$_2$E/ton of feedstock)
Transportation emissions (T_e)	0.008
Process emissions (P_e)	0.008
Fugitive CH_4 emissions (F_e)	0.078
Fugitive N_2O emissions (F_e)	0.025
Total	0.119

3.2 Compost Use Emission Reductions

Emission reductions occur when the composted product of organic municipal solid waste (MSW) is applied to an agricultural field. Numerous benefits may occur from compost applications, such as increased soil carbon storage, increased soil water retention, reduced fertilizer use, reduced herbicide use, decreased soil erosion, increased crop yield, and increased microbial activity. Quantifying these benefits in terms of greenhouse gas savings requires numerous approaches. In some cases, the benefits are not quantifiable from a greenhouse gas perspective.[39]

The section below quantifies the greenhouse gas benefit of applying compost to a soil system. Instead of presenting a single value, a range for each benefit (when possible) will be given.

3.2.1 Increased Soil Carbon Storage (CS_b)

There are three main types of carbon in composts with regard to carbon decay kinetics: fast, slow and passive. The fast and slow carbon, otherwise known as active carbon, degrades due to bacterial and fungal use of carbon compounds in the soil. The passive carbon content is made of humic substances, large organic macromolecules formed during the thermophilic stage of the composting process.[4] Passive carbon decays extremely slowly, if at all. In this method, a study that quantified the soil carbon storage separately for the active and passive carbon was used.[14]

The active portion of carbon in compost follows a first-order decay pattern. The study completed by USEPA used the CENTURY model to predict the active carbon decay.[14] The CENTURY model generated carbon storage scenarios for

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various applications of compost to an unamended soil. The carbon content was forecasted to 30 years beyond the compost application to evaluate the decay pattern of carbon in compost. The results indicated that the carbon storage of the active carbon phase due to compost application was 0.073 $MTCO_2E$/ton of feedstock.[14]

The passive carbon phase was completed out to a 30-year time series. The upper and lower bounds of carbon storage were determined by evaluating the amount of carbon that decayed slowly or was passive. The carbon storage value obtained for the passive carbon phase was 0.183 $MTCO_2E$/ton of feedstock. Combined together the overall carbon storage value was **0.256 $MTCO_2E$/ton of feedstock.**[14]

The fast carbon decay from the active soil phase was summed with relatively constant passive carbon phase to generate a 30-year decay graph for compost (see Figure 1). This curve was utilized for the water retention (W_b) and soil erosion (E_b) benefits described below.

A study completed by ICF International (2005) used the same numbers as described above to determine the soil carbon storage component of a composting emissions reduction factor for Canada.[54] Other studies have shown that the soil carbon storage is slightly lower. A study by Boldrin et al (2009)[9] estimates soil carbon storage in a range of 0.002-0.072 $MTCO_2E$/ton, while Blengini (2008) uses a range of 0.133-0.213 $MTCO_2E$/ton.[16] Other studies have qualitatively evaluated the soil carbon storage rates and concluded that it is occurring, even though quantification did not occur.[8,12]

3.2.2 Decreased Water Use (W_b)

Water benefits from applying compost to a soil system are due to the increased porosity and permeability of the soil. The California-specific study by Crohn (2010) indicates that compost applied to increase water retention on a fire affected site is 185 gallons/ton of compost and 678 gallons/ton of compost for the construction site for a one year time period.[35] The 30-year decay curve is presented in Figure 1. Studies have indicated that humic substances are a major contributor to increased surface water absorption, which allows the soil carbon decay curve to have applicability towards water retention.[4] Over 30 years, this equates to a benefit of 3550 and 13000 gallons/ton of compost for the fire affected and construction sites, respectively.[35] Converting gallons per ton of compost to acre feet (AF) and multiplying by the water use emission factor (1.5 $MTCO_2E$/AF) leads to a range of 0.015-0.065 $MTCO_2E$/ton of compost and an average of **0.04 $MTCO_2E$/ton of compost.** A series of other studies report a range of 118-810 gallons/ton of compost,[32-34] which is consistent with the numbers reported for this method. In addition to the above studies, it is important to note that other manuscripts report an increase in water retention and available water to plants due to compost application.[55-57] However, these studies did not report the variables necessary for inclusion into the above calculations.
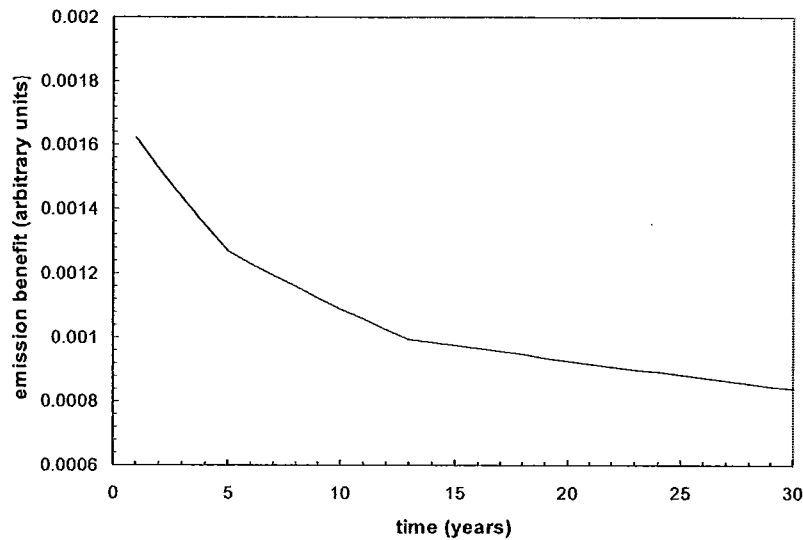
Figure 1. Decay curve used for the water retention (W_b) and decreased erosion benefits (E_b) of composting.

3.2.3 Decreased Soil Erosion (E_b)

Decreased erosion from addition of compost to soils is directly related to carbon content and water retention rates.[31] The curve in Figure 1 was used to determine the erosion capacity of compost. For initial inputs to the decay curve, the California-specific study by Crohn (2010) was used.[35] Compost applied to the fire affected site and construction site reduced soil erosion by 91 and 328 lbs/ton of compost on a 1-year timescale, respectively. This corresponds to a 30-year soil retention benefit of 1750 and 6300 lbs of soil/ton of compost for the fire affected and construction sites.

The emission factor used for this production was generated from the emissions associated with the composting process (Table 4). The emission factor is 0.119 $MTCO_2E$/ton of soil, which equates to an average savings of **0.25 $MTCO_2E$/ton of compost** and a range of 0.1-0.39 $MTCO_2E$/ton of compost (after being multiplied by the pounds of soil saved) over a 30-year time period.

The values used in this method are slightly higher than two other studies.[32,38] The values in the existing studies range from 33-64 lbs/ton of compost on the 1-year timescale.[32,38] However, these studies simulated single rain events, while the study by Crohn (2010), looked at multiple rain events over a longer time period.

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3.2.4 Decreased Fertilizer Use (F_b)

Fertilizer use in non-compost amended agricultural fields is often costly and leads to deleterious effects on soil health.[3] Amending a soil with compost has the ability to decrease the fertilizer requirement, but not totally eliminate the application.[43] Table 5 presents the NPK fertilizer benefits from compost application.

Table 5. Fertilizer benefit from compost application.[a]

	Percent weight (%)	Mass, 1-year (kg/ton of compost)	Mass, 10-year (kg/ton of compost)	Benefit, 10-year (MTCO$_2$E/ton of compost
Nitrogen (avg)[b]	1	9.1	24	0.21
Nitrogen (range)[c]	0.4-1.5	4.0-13.6	10.6-35.9	0.094-0.32
Phosphorous (avg)[d]	0.8	7.3	19.3	0.035
Phosphorous (range)[c]	0.0-1.6	0.1-14.5	0.3-38.3	0.0005-0.07
Potassium (avg)[e]	0.8	7.3	19.3	0.02
Potassium (range)[c]	0.3-1.3	2.7-11.9	7.1-31.4	0.007-0.03
			Average	0.26
			Range	0.1-0.42

[a] Reference 44. [b] n = 1215. [c] Range is based on a confidence level of 68% or one standard deviation (1σ). [d] n = 1356. [e] n = 1354.

The results from this method compare well with existing literature studies. The average fertilizer benefit from these studies was 0.17 MTCO$_2$E/ton of compost with a range of 0.14-0.32 MTCO$_2$E/ton of compost.[9,10,16]

3.2.5 Decreased Herbicide Use (H_b)

The quantitative results from a study that evaluated the effectiveness of compost at weed suppression were used. In this study, a glyphosate spray was applied to a bell pepper field and compared to other field plots that used compost or no amendment (control). The results indicated that compost was as effective as the herbicide.[46] Assuming a 100% replacement of herbicide by compost, the herbicide reduction value was multiplied by an emission factor that quantified the emissions associated with herbicide production.[46,48] This produces a measurable, but highly uncertain greenhouse gas benefit (< 0.001 MTCO$_2$E/ton of compost) due to the large amount of compost needed to achieve the same benefit as a small amount of herbicide. In terms of the overall contribution to the CERF, this benefit is negligible.

3.2.6 Conversion Factor (C_{use})

The conversion factor is used to convert from tons of compost to tons of initial feedstock. This conversion was done on a wet weight basis and is consistent with the method used for the composting emissions from section 3.1. Table 6 summarizes the studies used to determine this value.

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Table 6. Conversion factor inputs.

Reference	Feedstock	Initial mass (kg)	Final mass (kg)	Conversion factor
Hellmann et al (1997)[a]	Organic MSW, yard waste	31,520	20,890	0.66
Blengini et al (2008)[b]	Organic MSW	16,000,000	4,500,000	0.28
Boldrin et al (2009)[c]	Food waste, green waste	1,000	550	0.55
			Average	**0.50**
			Range	**0.28-0.66**

[a] Reference 28; [b] Reference 16; [c] Reference 9.

3.2.7 Summary of Emission Reductions

Table 7 presents the overall emission benefits from using compost.

Table 7. Summary of composting benefits (B_{total}).

Emission reduction type	Emission reduction (MTCO$_2$E/ton of compost)	Conversion factor	Final Emisson reduction (MTCO$_2$E/ton of feedstock)
Increased Soil Carbon Storage	N/A	N/A	0.26
Decreased Water Use	0.04	0.5	0.02
Decreased Soil Erosion	0.25	0.5	0.13
Decreased Fertilizer Use	0.26	0.5	0.13
Decreased Herbicide Use	0.0	0.5	0.0
		Total	**0.54**

3.3 Compost Emission Reduction Factor

The CERF is determined by subtracting the composting emissions (0.119 MTCO$_2$E/ton of feedstock) from the composting emission reductions (0.54 MTCO$_2$E/ton of feedstock).

This leads to a CERF of **0.42 MTCO$_2$E/ton of feedstock**.

3.4 Variability Analysis

The studies used to calculate each variable that contributed to the CERF were spread over a wide range of values. For instance, the fugitive CH$_4$ emissions ranged from 0.172 to 11.9 gCH$_4$/kg (Table 3) and the fertilizer benefits ranged from 0.08-0.30 MTCO$_2$E/ton of compost (Table 5). This wide range illustrates the uncertainty associated with each of these factors due to variability in the compost processing and in the physical properties of the soil to which the compost is

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added. In order to assess the possible range of CERF values, the following equation was used:

$$CERF_{range} = CERF_L \text{ to } CERF_H \qquad (4)$$

$$CERF_L = ((\Sigma\ B_{totL}) \times C_{useL}) - E_{totH} \qquad (5)$$

$$CERF_H = ((\Sigma\ B_{totH}) \times C_{useH}) - E_{totL} \qquad (6)$$

where,

$CERF_{range}$ = Possible range of the CERF based on evaluation of the lowest and highest compost emissions and benefits ($MTCO_2E$/ton of feedstock)

$CERF_L$ = Lowest possible CERF ($MTCO_2E$/ton of feedstock)

$CERF_H$ = Highest possible CERF ($MTCO_2E$/ton of feedstock)

B_{totL} = Sum of compost benefits based on the lowest values from this method ($MTCO_2E$/ton of compost) = 0.22 $MTCO_2E$/ton of compost

C_{useL} = 0.28 ton of feedstock/ton of compost

E_{totH} = Sum of compost emissions based on the highest values from this method ($MTCO_2E$/ton of feedstock) = 0.28 $MTCO_2E$/ton of feedstock

B_{totH} = Sum of compost benefits based on the highest values from this method ($MTCO_2E$/ton of compost) = 1.39 $MTCO_2E$/ton of compost

C_{useH} = 0.66 ton of feedstock/ton of compost

E_{totL} = Sum of compost emissions based on the lowest values from this method ($MTCO_2E$/ton of feedstock) = 0.017 $MTCO_2E$/ton of feedstock

Applying the values for each variable, the $CERF_{range}$ is -0.22 to 0.90 $MTCO_2E$/ton of feedstock. In order to use the correct units for the soil carbon storage variable, the 0.26 $MTCO_2E$/ton of feedstock value reported in Section 3.2.1 was multiplied by two to account for the feedstock to compost conversion for B_{totH} and the 0.002 $MTCO_2E$/ton of feedstock (from Reference 16) was multiplied by two for B_{totL}. The average between $CERF_L$ and $CERF_H$ is 0.34 $MTCO_2E$/ton of feedstock. This value is slightly lower than the CERF (0.42 $MTCO_2E$/ton of feedstock).

The CERF obtained from this method has uncertainties due to the lack of general scientific understanding of some physical processes of compost application, absence of literature articles, and reliance on non-California specific study locations.

The application of compost to a non-amended soil provides soil benefits (benefits were discussed in this method). Uncertainties occur when researchers attempt to link a specific compost benefit to a modification of soil properties. For example, soil type plays a large role in the magnitude of a compost benefit. It is unclear what factors (type, size, pH, etc) of the mineral composition of the parent soil impact the compost benefit.

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Current compost literature focuses mainly on the fugitive emissions[15,19,20,27-29] that occur during the composting process. Few studies evaluate the process emissions or the benefits from the end uses of compost. The most prevalent composting benefits discussed in the literature was increased soil carbon storage[9,14,16] and decreased fertilizer use[9,10,16,44]. Additionally, the erosion and water use results were extrapolated from laboratory-scale experiments as opposed to macroscale field methods. Extrapolating the data may skew the results, depending on the physical properties of the compost. The herbicide results are based on only one study.[46] It was difficult to obtain reliable results from a single experiment, plus life-cycle information on herbicides was difficult to obtain and a pesticide life-cycle was used as a proxy.[48]

This method was able find some California-specific compost studies to use for quantification (process emissions, transportation emissions, reduced water use, reduced soil erosion, and reduced fertilizer use). The other studies came from the United States (soil carbon storage and reduced herbicide use) or well-reputed international sources (fugitive emissions were modified from IPCC data).

As additional research is completed, the uncertainties will diminish. In the interim, it is important to understand the shortcomings of this quantification method and apply them in a judicious manner.

4. SUMMARY

This method presents a compost emission reduction factor (CERF) for composting in California. This method accounts for the emissions (transportation, process, and fugitive) from the composting process and the benefits of applying (increased carbon storage, reduced water use, reduced soil erosion, decreased fertilizer use, and decreased herbicide use) compost as a soil amendment. A summary of the emissions and emission reductions are shown in Table 8.

Table 8. Summary of compost emission reduction factory (CERF).[a]

Emissions			
		Emission type	Emission (MTCO$_2$E/ton of feedstock)
		Transportation emissions (T$_e$)	0.008
		Process emissions (P$_e$)	0.008
		Fugitive CH$_4$ emissions (F$_e$)	0.078
		Fugitive N$_2$O emissions (F$_e$)	0.025
		Total	0.119

Emission reductions			
Emission reduction type	Emission reduction ($MTCO_2E$/ton of compost)	Conversion factor	Final Emisson reduction ($MTCO_2E$/ton of feedstock)
Increased Soil Carbon Storage (Cs_b)	N/A	N/A	0.26
Decreased Water Use (W_b)	0.04	0.5	0.02
Decreased Soil Erosion (E_b)	0.25	0.5	0.13
Decreased Fertilizer Use (F_b)	0.26	0.5	0.13
Decreased Herbicide Use (H_b)	0.0	0.5	0.0
		Total	0.54
		Overall	0.42

[a] The CERF was determined by subtracting the emissions from the emission reductions.

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EXHIBIT "F"

**METHOD FOR ESTIMATING
GREENHOUSE GAS EMISSION REDUCTIONS FROM RECYCLING**

November 14, 2011

Planning and Technical Support Division

California Air Resources Board

California Environmental Protection Agency

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Method for Estimating
Greenhouse Gas Emission Reductions from Recycling

EXECUTIVE SUMMARY

This method quantifies the material-specific greenhouse gas emission reduction benefits associated with recycling. The life-cycle approach used in this method incorporates avoided emissions from manufacturing using recyclables, the use of raw materials in the manufacturing process (i.e., harvested wood), transportation emissions, and recycling efficiency. The following equation is used to calculate each recycling emission reduction factor (except dimensional lumber; RERF):

$$RERF = ((MS_{virgin} - MS_{recycled}) + FCS - T_{remanufacture}) * R_{use}$$

where,

RERF	=	Recycling emission reduction factor ($MTCO_2E$/ton of material)
MS_{virgin}	=	Emissions associated with using 100% virgin inputs for manufacturing the material ($MTCO_2E$/ton of material)
$MS_{recycled}$	=	Emissions associated with using 100% recycled inputs for manufacturing the material ($MTCO_2E$/ton of material)
FCS	=	Forest carbon sequestration ($MTCO_2E$/ton of material)
$T_{remanufacture}$	=	Transportation emissions associated with remanufacture destination ($MTCO_2E$/ton of material)
R_{use}	=	Recycling efficiency (fraction of material remanufactured from ton of recycled material)

The above equation uses an approach similar to one established by the United States Environmental Protection Agency (USEPA). This method modified USEPA's approach to include California-specific data and added a model to evaluate forest carbon sequestration. A summary is shown in Table ES-1.

Table ES-1. Recycling emission reduction factors (RERFs) for each material.

Material	RERF[a]	Material	RERF[a]
Aluminum	12.9	Magazines/3rd class mail	0.3
Steel	1.5	Newspaper	3.4
Glass	0.2	Office paper	4.3
HDPE	0.8	Telephone books	2.7
PET	1.4	Dimensional lumber	0.21
Corrugated cardboard	5.0	Mixed Plastics[b]	1.2

[a] Units are in $MTCO_2E$/ton of material.
[b] The mixed plastics average assumes a mix of 71% PET and 29% HDPE.

A qualitative uncertainty analysis performed for each of the above variables shows that the RERFs used in this method are in an appropriate range (with respect to the sensitivities of each variable) for each material. A literature review indicates each RERF is comparable to other emission factors in existing studies.

1. BACKGROUND

The benefits of recycling are multifaceted and range from the reduction of metal pollutants in leachate[1] to the reduction of greenhouse gas emissions[2-6]. In the past decade, many studies have discussed assigning specific materials greenhouse gas (GHG) emission reduction factors associated with recycling.[4,5,7,8] The GHG emission reduction factors are designed to encourage recycling from a climate change perspective and are typically based on relative emission reduction benefits. In the United States Environmental Protection Agency (USEPA) Waste Reduction Model (WARM), emission benefits of recycling, composting, or combusting wastes are calculated relative to landfilling.[4] Also, USEPA acknowledges that WARM is a planning tool and should not be used to quantify for greenhouse gas emission reductions in an accounting scheme (such as a GHG inventory).[4]

Greenhouse gas benefits from recycling are determined by using a life cycle approach that compares virgin material manufacturing with recycled material manufacturing.[9,10] For inorganic materials (i.e., aluminum, glass, steel, plastics), the manufacturing stage is limited to emissions associated with obtaining raw materials and raw material processing at the manufacturing location.[4,11] The manufacturing inputs for wood-based organic materials (i.e., office paper and newspaper) are similar to inorganic materials, but include a factor to account for forest carbon sequestration.[4] Forest carbon sequestration benefits from recycling result from the avoided emissions associated with tree harvesting and from the additional carbon storage in a tree that would have been harvested in the absence of recycling.[12-15] Forest carbon sequestration is difficult to quantify, leading most analyses to only qualitatively assess the benefit as greater than zero.[14,16] One study, conducted by the USEPA, quantifies the forest carbon sequestration benefit based upon the avoided emissions from mechanical or chemical pulp processing.[4] The results from WARM for forest carbon sequestration employ a stock change approach and are applicable to national-level planning goals for recycling.[4] The greenhouse gas inventory for forests in California uses an atmospheric flow model, which contrasts with the national model.[17]

The purpose of this method is to generate recycling emission reduction factors (RERFs) that are consistent with GHG accounting practices used in California. The RERFs calculated from this method are not intended to replace existing studies. This method estimates RERFs for the following materials: aluminum cans, steel cans, glass, high density polyethylene (HDPE), polyethylene terephthalate (PET), corrugated cardboard, magazines/3rd class mail, newspaper, office paper, phonebooks, dimensional lumber and mixed plastics (mix of HDPE and PET). The emission reduction factors are calculated from the best available data sources and include quantification methods for the process and transportation emissions associated with manufacturing, a forest carbon sequestration factor, transportation emissions associated with moving the recovered material to its point of remanufacture, and a recycling efficiency term. Lastly, a comparison to literature-

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based studies and a sensitivity analysis will be completed to validate this method in the context of existing work.

2. METHODS

The methods used to determine the RERFs for each material are described in the following section. The boundary,[18] or life cycle stages used to quantify each RERF, for this method defines the emission benefits of recycling, including manufacturing emissions and forest carbon sequestration. In addition, the transportation emissions associated with moving the recycled material to its point of remanufacturing will be considered as well as the recycling efficiency.

2.1 Process and transportation emissions

Life cycle greenhouse gas emissions associated with a manufactured material may be calculated as follows:

$$LCA = MS + US + EOLS \tag{1}$$

where,
LCA	=	Life cycle greenhouse gas emissions of the material.
MS	=	Emissions associated with the manufacturing stage of the material
US	=	Emissions associated with the use stage of the material
EOLS	=	Emissions associated with the end of life stage of a material

The manufacturing stage includes the emissions associated with the generation of a particular material. This includes emissions from the mining, extraction, processing and transportation of the material inputs. The use stage accounts for the energy required to use the material or transform it into usable product. The end-of-life-stage includes material disposal. End-of-life options include landfilling, recycling, composting, or combusting the material.

When evaluating the life cycle emissions reductions due to recycling, the following equation applies:

$$LCA_{total} = (MS_{virgin} + US_{virgin} + EOLS_{virgin}) - (MS_{recycled} + US_{recycled} + EOLS_{recycled}) \tag{2}$$

Assuming $US_{virgin} = US_{recycled}$ and $EOLS_{virgin} = EOLS_{recycled}$, then

$$LCA_{total} = MS_{virgin} - MS_{recycled} \tag{3}$$

where,
LCA_{total}	=	Total life cycle emissions associated with recycling
MS_{virgin}	=	Emissions associated with using 100% virgin inputs for manufacturing the material

US$_{virgin}$	=	Emissions associated with the use stage of the virgin material
EOLS$_{virgin}$	=	Emissions associated with the end of life stage of the virgin material
MS$_{recycled}$	=	Emissions associated with using 100% recycled inputs for manufacturing the material
US$_{recycled}$	=	Emissions associated with the use stage of the recycled material
EOLS$_{recylced}$	=	Emissions associated with the end of life stage of the recycled material

The manufacturing datasets for each material were obtained from three main sources in Table 1.

Table 1. Material references for upstream process and transportation emissions.

Material	Reference
Aluminum	USEPA (1998)[a], USEPA (2003)[b]
Steel	USEPA (1998)
Glass	USEPA (2003)
HDPE	USEPA (1998), USEPA (2003)
PET	USEPA (1998), USEPA (2003)
Corrugated cardboard	USEPA (1998), USEPA (2003)
Magazines/3rd class mail	USEPA (2003)
Newspaper	USEPA (1998), USEPA (2003)
Office Paper	USEPA (1998), USEPA (2003)
Phonebooks	USEPA (1998), USEPA (2003)

[a] Ref. 10; [b] Ref. 9.

Datasets consisted of process emissions (emissions associated with manufacturing a material) and transportation emissions (emissions associated with transporting the raw inputs to the production site) for the manufacture of a particular material in a closed loop system. A closed loop system implies that recycled products are used to make a similar product (i.e., recycled aluminum cans are used to make more aluminum cans or office paper is used to make more office paper).[19] More detailed calculations for the raw data used to obtain the process and transportation emissions is shown in the Supplemental Spreadsheet. In two cases, the manufacturing process inputs included a recycled material component; virgin steel includes 20% recycled material and virgin cardboard contains 10% recycled material.[10]

With respect to electricity used in manufacturing, a national electricity emission factor was used because the manufacturing stage of each material does not necessarily take place in California.[20,21] Emission factors for various fuel types were obtained from the ARB's Local Government Operations Protocol[22] as a primary option and other sources as a secondary choice.[23,24] For all upstream process and transportation emissions, emissions for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were calculated, multiplied by their global

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warming potentials (1 for CO_2, 21 for CH_4 and 310 for N_2O) and summed together in units of carbon dioxide equivalents(CO_2E; see Supplemental Spreadsheet).

Emissions associated with precombustion[25] (i.e., emissions associated with mining the fuels used in the manufacturing stage) were included in this method. Precombustion emissions were omitted for steel due to lack of data for this material. The precombustion emissions come from a single source.[9] The reported process and transportation emissions are an average of the two datasets (when applicable).[9,10]

2.2 Recycling Efficiency Factor

Studies have shown that recycled material is not fully recovered at a recycling facility nor is the recycled material used in a 100% capacity at the remanufacturing facility.[4] In order to account for these collection and use inefficiencies, a material-specific recycling efficiency factor will be applied to the RERF. The recycling efficiency factor is based on a previous study completed by the USEPA (Table 2).[4]

Table 2. Recycling efficiencies of each material.

Material	Recycling recovery efficiency (%) (a)	Recycling remanufacture efficiency (b)	Recycling efficiency (a x b)
Aluminum	100	0.93	0.93
Steel	100	0.98	0.98
Glass	90	0.98	0.88
HDPE	90	0.86	0.77
PET	90	0.86	0.77
Corrugated cardboard	100	0.93	0.93
Magazines/3rd class mail	95	0.71	0.67
Newspaper	95	0.94	0.89
Office Paper	91	0.66	0.60
Phonebooks	95	0.71	0.67

2.3 Transportation Correction Factor

The transportation emissions associated with moving the recycled material to its remanufacturing stage affects the overall RERF. In order to account for this, a correction factor will be applied to the RERF. Studies conducted by the California Department of Conservation,[26] the California Integrated Waste Management Board,[27] and the American Forest and Paper Association[28] produced data used to determine the final destination of the recycled material (Table 3).

Table 3. Remanufacturing distribution of recycled materials in California.

Material	Remanufacturing Destination
Aluminum[a]	99% Southeast, 1% Mexico, Europe, Brazil
Steel[b]	90% Pacific Rim, 10% California
Glass[a]	85 % California, 15% in Mexico, Texas, Colorado, Washington, Oklahoma
HDPE[a]	46 % California, 36 % in China, 18 % Southeast
PET[a]	77% China, 10 % Southeast, 14% California
Corrugated cardboard[c]	36% China, 64% United States mix
Magazines/3rd class mail[c]	36% China, 64% United States mix
Newspaper[c]	36% China, 64% United States mix
Office paper[c]	36% China, 64% United States mix
Phonebooks[c]	36% China, 64% United States mix

[a] Ref. 26. The data from this source is based on recycled beverage containers.
[b] Ref. 27.
[c] Ref. 28. The American Forest and Paper Association does not disaggregate to the state level. For more information, please see: http://paperrecycles.org/stat_pages/recovered_paper_goes.html.

The transportation miles were based on transportation scenarios within California, within North America, and overseas transport (Table 4). The transportation assumptions were based on average distances to each location and was sensitive to non-ocean going vessel transport at the destination site. For example, travel assumption 4 (International: Asia) assumes an average of 60 miles of truck and 300 miles of rail travel in California and 140 miles of truck and 700 miles of rail travel in its destination country. Transport emission factors were applied uniformly to all legs of the trip.

Using the appropriate fuel emission factors, greenhouse gas emissions from transportation were calculated for each transportation type: truck (101 g CO_2/net ton-mile), rail (22 g CO_2/net ton-mile) and ocean going vessel (19 g CO_2/net ton-mile).[29] The truck value is based on a California instate tractor trailer emission factor. Other types of trucks (e.g., drayage trucks or trucks that travel in multi-states) have varying emission factors, but only change the overall emission factor by ~1%.[30] The rail emission factor is based on fuel consumption rates provided by the Association of American Railroads[31] and a diesel emission factor from the Local Government Operations Protocol[22]. The ocean going vessel emission factor was generated from the ARB Marine Model, Version 2.3.[32] For information about the results the Marine Model produces, please see the Emissions Estimation Methodology for Ocean Going Vessels.[33]

Table 4. Transportation assumptions for recycled materials in California.

Destination	Truck miles	Rail miles	Ocean going vessel miles*	Justification
1.California	60	300	0	The majority of recycled materials in California are transported out of state by rail or ocean-going vessel. The major ports in California are located near population centers. On average, the trips in the population centers will have lower truck and rail miles, while transporting recycled goods to their remanufacturing location within in California may have higher truck and rail miles.
2. United States (Southeast)	200	2300	0	Most aluminum smelters that accept aluminum recycled in California are located in the Southeast. The Southeast destination assumes a trip that leaves California and arrives in Alabama as an average trip to the Southeast
3. United States (average)	200	1600	0	The trip mileage in this scenario assumes the average trip ends up in the Midwest.
4. International (Asia)	200	1000	7000	The trip mileage in this scenario accounts for the truck and rail miles associated with getting the recycled material to a port. The destination of the recycled goods is Mainland China and truck and rail mileage is included for transporting the goods in China.
5. International (other)	200	2000	4000	This mileage scenario assumes an average destination between Europe and South America (Brazil). It includes truck and rail transportation in California and the destination country.

*Ocean going vessel miles are based on nautical miles.

2.4 Forest Carbon Sequestration

A chemical composition approach was taken to assign a forest carbon sequestration factor to each wood-based organic material (corrugated cardboard, magazines/3rd class mail, newspaper, office paper, phonebooks, and dimensional lumber). On average, a tree contains about 50 percent carbon on a dry weight basis, with the rest of the elemental composition mainly hydrogen, oxygen, nitrogen, and other trace elements.[34] Additionally, information is available on the amount of harvested wood (not including bark, leaves, small stems, etc.) it takes to make a specific unit of material.[35,36] Table 5 shows the amount of virgin wood required to produce a ton of given paper product.

Product	Amount of wood needed (lbs/ton)
Corrugated cardboard[a]	6,060
Newspaper[a]	4,180
Office Paper[a]	6,940
Magazines/3rd class mail[a,b]	6,940
Phonebooks[a,c]	4,180

[a] Ref. 36.

[b] Amount of wood needed for magazines is the same for office paper due to similar processing methods.

[c] Amount of wood needed for phonebooks is the same for newspaper due to similar processing methods.

When a tree is harvested from a forest, the carbon sequestration potential of the harvested tree is no longer available because it has stopped growing. Recycling a wood-based organic material alleviates the need to harvest trees because recycled wood products are substituted for virgin material. For this reason, the carbon sequestered by a tree due to recycling can be considered to be the growth of a non-harvested tree after the expected year of harvest.

$$FCS = \text{Carbon sequestered in tree (MTCO}_2\text{E)} = \sum_{h}^{99} (V_{h+1} - V_h) * d_t * 0.5 * 0.00016636 \quad (4)$$

where:

h	=	year the tree is harvested
V_h	=	volume of the tree in the hth year (ft³)
V_{h+1}	=	volume of the tree in the (h+1)[th] year (ft³)
d_t	=	density of the tree, dry weight basis (lb/ft³)
0.5	=	factor converting total mass of tree to carbon content
0.00016636	=	factor converting total carbon content to MTCO₂E (includes factor for tree survival rate)[37]

The above equation (4) was used to calculate a forest carbon sequestration for each wood-based organic material.

The Forest Carbon Sequestration (FCS) model represents an average, or "theoretical" tree used in the production of wood products. The theoretical tree consists only of the trunk. The leaves, bark, stems, branches and roots were not considered in this model. The theoretical tree was based upon empirical loblolly pine (*Pinus taeda*) data that consisted of a Site Index of 80 (i.e., average tree height after 50 years is 80 feet for a given stand) for a natural pine plantation that lives 100 years[38,39]. The loblolly pine was chosen because it has a wide range in the Southeastern United States, is the most commercially viable species in this region, and is commonly used for pulp production and dimensional lumber[40,41]. The height of the tree as a function of time was constructed from two different sources and the diameter at breast height (dbh) was calculated using a tree growth

rate table.[39,42] It was assumed that the tree had a dendrochronology of approximately 5 incremental growths per inch in its early life phases, which slowed to around 7 as the tree approached 100 years in age.[42] The volume of the tree was calculated by using a bole approach.[43] For this method, the middle portion (above the dbh and below the top section) of the tree was divided into tapered regions (up to 9, depending on height) and the top of the tree was modeled as a cone, while below the dbh was assumed a cylinder.

Once the volume was calculated, the increased growth was calculated by determining the volume increase on a yearly basis (e.g. volume in year 26 minus volume in year 25). The harvest year (h, equation 4) was year 25. The weight of the tree was determined by multiplying the volume by the density. The weight was divided by a factor of 2 to account for carbon content and then converted to units of $MTCO_2E$/tree (Equation 4). Lastly, the tree carbon sequestration value (Equation 4) was then divided by 10 to account for the mortality rate of the tree.[45-47]

2.5 Final recycling emission reduction factor (RERF)

The above four sections describe each variable under consideration for determining the RERF. The emission reductions from recycling occur during the manufacturing stage and the with forest carbon sequestration. The emissions occur during the transportation of the recovered material to its remanufacturing emissions. The sum of these above terms is then corrected by the recycling efficiency term. The final RERF value was obtained using the following equation:

$$RERF = ((MS_{virgin} - MS_{recycled}) + FCS - T_{remanufacture}) * R_{use} \qquad (5)$$

where,

RERF	=	Recycling emission reduction factor ($MTCO_2E$/ton of material)
MS_{virgin}	=	Emissions associated with using 100% virgin inputs for manufacturing the material ($MTCO_2E$/ton of material)
$MS_{recycled}$	=	Emissions associated with using 100% recycled inputs for manufacturing the material ($MTCO_2E$/ton of material)
FCS	=	Forest carbon sequestration ($MTCO_2E$/ton of material)
$T_{remanufacture}$	=	Transportation emissions associated with remanufature destination ($MTCO_2E$/ton of material)
R_{use}	=	Recycling efficiency (fraction of material remanufactured from ton of recycled material)

2.6 Emission reduction factor for dimensional lumber

Recycled dimensional lumber (e.g. 4x4, 2x4, 1x8 etc.) does not exhibit closed loop recycling in California. Instead, recycled lumber is chipped and used for biomass combustion. The recycling emission reduction factor for dimensional lumber was determined using the following equation:

$$RERF_{DL} = DL_b - DL_e \qquad (6)$$

where (all units in $MTCO_2E$/ton of lumber)
$RERF_{DL}$ = recycling emission reduction factor for dimensional lumber
DL_b = avoided emissions associated with recycling dimensional lumber
DL_e = emissions associated with processing recycled dimensional lumber

Recycling dimensional lumber increases biomass use for electricity generation, which alleviates the need to use fossil-fuel based energy sources. This was simulated by applying a California grid average electricity emission factor as the avoided emissions from using biomass.[22] It was also assumed that 1 dry ton of wood chips is equivalent to 2 green tons of lumber and 1 dry ton of wood chips is able to generate 1 MWh of electricity.[48] This value is conservative due to the drying steps lumber goes through during processing. Emissions from the biomass burning were not included in this calculation. The carbon dioxide emissions from biomass burning are considered biogenic and the methane and nitrous oxide emissions are small (0.006 $MTCO_2E$/MWh) when compared to the overall RERF. The emissions from processing recycling dimensional lumber into wood chip biomass were determined by evaluating the chipping rate from a standard chipper (3.3 dry tons/hour) and emissions (19.8 kg CO_2/hr).[49,50]

3. RESULTS AND DISCUSSION

The results of this method and a discussion that evaluates the validity of the recycling emission reduction factors (RERFs) are presented below. The first five sections focus on the inputs used to determine each RERF. The last sections present a qualitative uncertainty analysis of the method and a comparison of the results with the literature for each material.

3.1 Process and Transportation Emissions

This section evaluates the process and transportation emissions included in the RERF calculations. As described in the methods section, the boundaries for these emissions are restricted to the manufacturing stage of the life cycle. The emissions include all emissions associated with the production of a particular material.

The process and transportation emissions (including precombustion) for each material are shown in Tables 6, 7 and 8. An average of two studies[9,10] was used when available. In some cases, the raw transportation data were not included in the study. In these instances, the overall emission factor included only process emissions or the transportation data from USEPA (1998)[10] were used as a proxy for omitted USEPA (2003)[9] transportation data. Even though the transportation emission data set was not complete for all materials, the contribution of transportation emissions to the overall upstream emission value was generally small.

Table 6. Manufacturing stage emissions for each material.[a]

Material	Production Using Virgin Material Inputs						Total Emissions
	Process Emissions			Transportation Emissions			
	USEPA (1998)[b]	USEPA (2003)[c]	Average[d]	USEPA (1998)[b]	USEPA (2003)[c]	Average[d]	
Aluminum	13.3	14.1	13.7	0.3	0.5	0.4	14.1
Steel	2.0		2.0	0.1		0.1	2.1
Glass		0.34	0.34		0.04	0.04	0.38
HDPE	1.3	1.4	1.35	0.1	N/A[e]	0.1	1.4
PET	2.1	1.4	1.75	0.2	N/A[e]	0.2	2.0
Corrugated cardboard	2.3	2.2	2.25	0.1	0.1	0.1	2.4
Magazines/3rd class mail		2.3	2.3		N/A	N/A[f]	2.3
newspaper	2.0	2.4	2.2	0.1	0.03	0.07	2.3
office paper	4.4	3.1	3.75	0.2		0.2	3.9
phonebooks		2.6	2.6		N/A	N/A[f]	2.6
Production Using Recycled Material Inputs							
Aluminum	0.36	0.86	0.61	0.003	0.002	0.0025	0.6
Steel	0.35		0.35	0.08		0.08	0.4
Glass		0.21	0.21		0.02	0.02	0.23
HDPE	0.4	0.14	0.27	0.1	N/A[e]	0.1	0.37
PET	0.4	0.14	0.27	0.1	N/A[e]	0.1	0.37
Corrugated cardboard	1.1	0.9	1.0	0.1	0.1	0.1	1.1
Magazines/3rd class mail		2.2	2.2		N/A	N/A[f]	2.2
newspaper	1.3	1.2	1.25	0.05	0.002	0.026	1.3
office paper	1.6	1.3	1.45	0.1	0.06	0.08	1.5
phonebooks		1.4	1.4		N/A	N/A[f]	1.4

[a] All units are in $MTCO_2E$/ton of material.

b Ref. 10.

[c] Ref. 9.

[d] For steel cans, glass, magazines/3rd class mail, and phonebooks the average consists of only one value. Even though an n=1 does not constitute an average, this value was placed in this column for consistency purposes.

[e] The transportation data for HDPE and PET were not included in Reference 9. For this reason, the process emissions were averaged but only one transportation value was used.

[f] The transportation data was not included in Reference 9. It is assumed for magazines/3rd class mail and phonebooks that the transportation factor contributes negligibly to the overall emission reduction factor.

Table 7. Precombustion emissions for the manufacturing stage of each material.[a,b]

Material	Primary Production (virgin material)	Secondary Production (recycled material)
Aluminum	0.53	0.07
Steel[c]	N/A[d]	N/A[d]
Glass	0.12	0.03
HDPE	0.21	0.06
PET	0.43	0.06
Corrugated cardboard	0.03	0.03
Magazines/3rd class mail	0.07	0.07
Newspaper	0.16	0.09
Office Paper	0.04	0.06
Telephone books	0.11	0.06

[a] Units are in $MTCO_2E$/ton of material.
[b] The precombustion emissions were generated from Ref. 9.
[c] Precombustion emissions for steel was not included in Ref. 9.
[d] N/A = not available.

Table 8. Summary of the manufacturing emission reductions (sum of process and precombustion) for each material.[a,b]

Material	Primary production (virgin material) (a)	Secondary production (recycled material) (b)	Total manufacturing emission reductions (a-b)	Percent Reduction (%) ((a-b)/a)
Aluminum	14.6	0.7	14.0	95.9
Steel[c]	2.1	0.4	1.7	81.0
Glass	0.5	0.26	0.2	40.0
HDPE	1.6	0.43	1.1	68.8
PET	2.4	0.43	2.0	83.3
Corrugated cardboard	2.4	1.1	1.3	55.3
Magazines/3rd class mail	2.4	2.3	0.1	4.2
Newspaper	2.5	1.4	1.0	40.0
Office Paper	3.9	1.6	2.4	61.5
Telephone books	2.7	1.5	1.2	44.4

[a] Units are in $MTCO_2E$/ton of material, unless noted.
[b] The reported numbers from (a) and (b) may not sum together due to rounding.
[c] Steel does not have emissions from precombustion included.

The final emission reduction values vary for each material. The material with the highest reductions associated with recycling instead of using virgin material is aluminum (14.0 $MTCO_2E$/ton) while the lowest is magazines/3rd class mail (0.1 $MTCO_2E$/ton). The reason for the large discrepancies in each material type is due to the varied production mechanisms that occur. Aluminum refining requires a

large electricity input while the production of glass (0.2 $MTCO_2E$/ton) does not require such an intensive use of electricity.

3.2 Transportation Correction Factor

Using the assumptions for recycled product distribution (Table 3) and miles travelled to reach that destination (Table 4), the overall transportation emissions associated with each material is shown in Table 9. This value specifically addresses the transportation associated with moving the recycled material from the location it was recovered to its remanufacturing destination. In many cases, this information may also be included in the transportation emissions that are included in the 100% recycled data (Table 6). However, the recycling transportation data listed in Table 6 does not disaggregate the transportation emissions from moving the recycled material from the total transportation emissions needed to remanufacture the recycled material.[10] For this reason, the $T_{remanufacture}$ term is included in the method, with the assumption that the recycling transportation term in the manufacturing stage (Table 6) may overlap with this term. This assumption leads to a more conservative RERF (by about 3%, on average).

Table 9. Destination assumptions used and $T_{remanufacture}$ for each material.

Material	Assumptions[a]	Emissions[b,c]
aluminum	2, 5	0.07
steel	1, 4	0.16
glass	1, 3	0.02
HDPE	1,2, 4	0.08
PET	1, 2, 4	0.14
corrugated cardboard	3, 4	0.10
magazines/3rd class mail	3, 4	0.10
newspaper	3, 4	0.10
office paper	3, 4	0.10
phonebooks	3, 4	0.10

[a] The assumption number corresponds to the mileage assumptions in Table 4 and are based upon the data accumulated in Table 3.

[b] The emission factors associated with the forms of transportation are: trucks - 101 g CO_2/net ton-mile, rail – 22 g CO_2/net ton-mile, and ocean going vessels – 19 g CO_2/net ton-mile (See Methods section for a list of references). The total transportation emission value was generated by multiplying the proportion of materials transported to each destination (i.e., California, etc.) by the amount of miles associated with each trip leg.

[c] Unit are in $MTCO_2E$/ton of material.

The destination values used for aluminum are based on a qualitative description because an exact number was not available.[26,51] Additionally, the value used for wood-based organic materials is a United States average number.[28] Due to the small magnitude of the emissions from $T_{remanufacture}$, the majority of the RERF value will be determined by the manufacturing emission savings and forest carbon sequestration (for wood-based organic materials only).

3.3 Forest Carbon Sequestration

The theoretical tree model was designed to compute the forest carbon sequestration potential for recycling each type of wood-based organic material. The model only includes the marketable component of the tree (i.e., trunk) and does not include any leaves, stems, roots or branches in the calculations. While carbon storage does occur in other parts of the tree besides the trunk,[52] a conservative approach is used in this study. The trunk of the tree was modeled based on *P. taeda* (loblolly pine) and the trunk dbh (Figure 1) and height (Figure 2) as a function of age were generated from previous studies.[38,39]

The dbh was determined from a study that showed an average loblolly pine dbh is 5.9 inches at a height of 35 feet and 11 inches at 66 feet.[38] This experimental information was combined with tree growth charts that estimated growth from the number of tree rings in the outer inch of the trunk.[39,42] To match the height curve, it was estimated that the growth in the diameter at breast height (dbh) was 3% from year 41-60, 2.2% from year 61-70, 1.2% from year 71-85 and 0.5% from year 85-100 (about 7 rings in the outer inch of the trunk). The height curve was consistent with a study completed by the Cooperative Extension Service at the University of Georgia.[39]

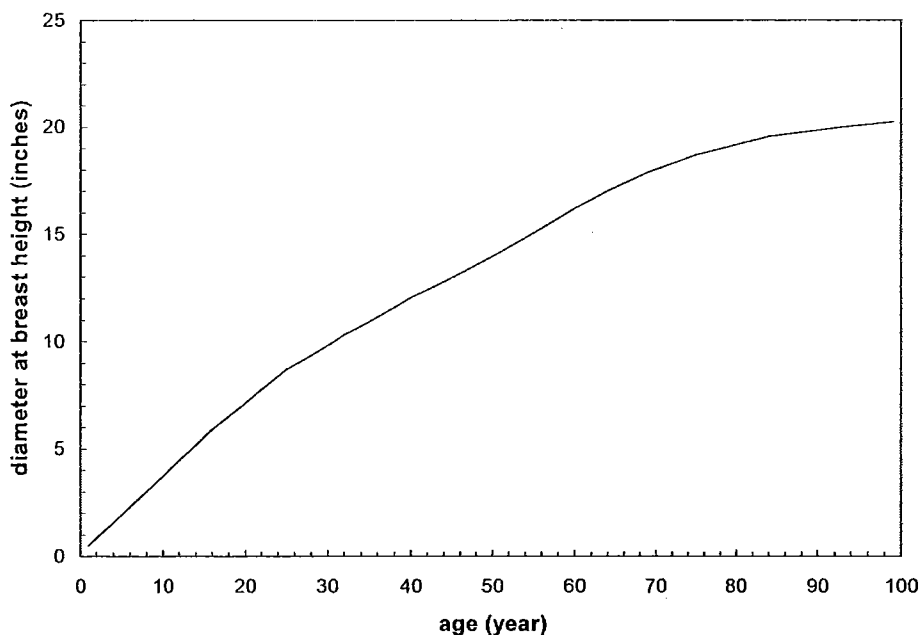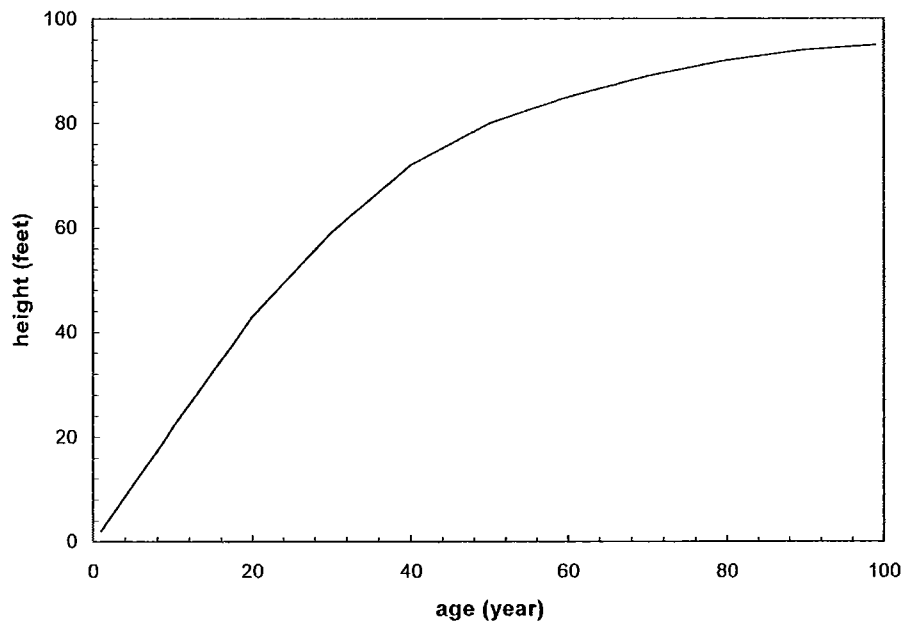**Figure 1.** Graph showing the dbh of a tree as a function of age.

Figure 2. Graph showing the height of a tree as a function of age.

The incremental carbon storage per year (years 26-100) is shown in Figure 3. The growth curve is consistent with the slope of the curves for height and dbh (Figures 1 and 2). The sum of the incremental carbon storage from years 26-100 was 1.90 $MTCO_2E$/tree. Assuming an exponential death/harvest rate,[47] coupled with two experimental data points,[38] only 10% of the original trees survived to year 100. Because of this survival rate, the amount of carbon stored per tree was divided by ten to account for trees standing at 100 years. Therefore, the carbon storage value on a per tree basis is 0.19 $MTCO_2E$/tree.

Figure 3. Graph indicating the amount of incremental carbon stored (MTCO₂E/year) over the lifetime of a tree that was not harvested at year 25 due to recycling. The value at each year increment was generated using the theoretical tree model. The area under the curve was summed and divided by 10 to determine the overall amount of carbon sequestered in a single tree to year 100.
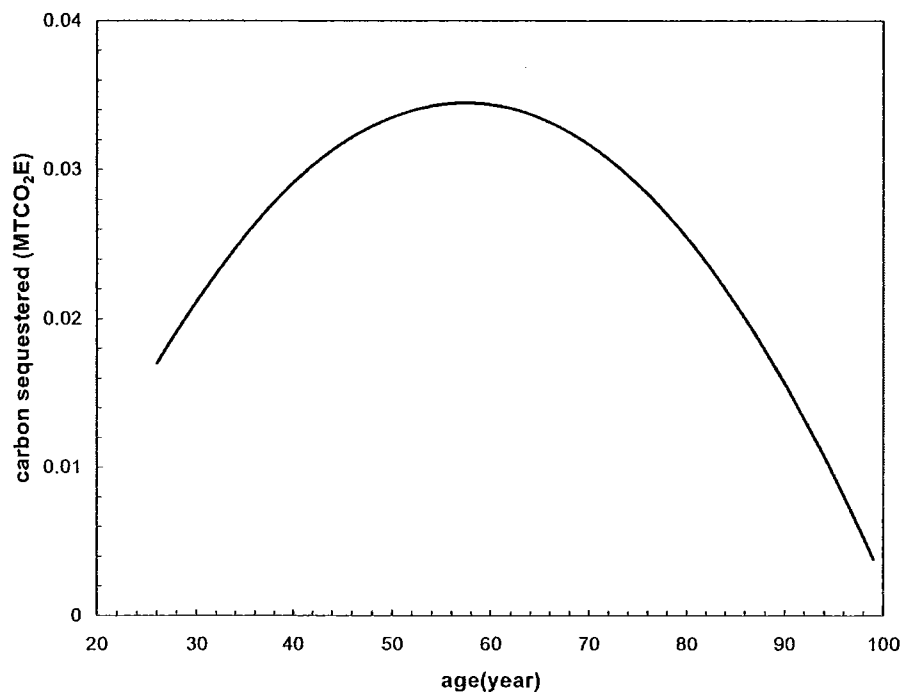
At year 25, the theoretical tree is harvested with a weight of 274 lbs. By year 100, the tree has attained a weight of 2594 lbs that equates to a volume of 2.5 m^3, assuming a density of 29.33 lb/ft^3.[44] Utilizing the data from Table 5 and the weight of tree at harvest, an average number of trees/ton per material produced and a forest carbon sequestration factor were generated (Table 10).[35,36]

Table 10. Amount of trees used to produce one ton of wood-based organic material and the corresponding forest carbon sequestration.

Material	Tree equivalents (trees/ton of material produced)[a]	Forest carbon sequestration factor (MTCO₂E/ton of material)[b]
Corrugated cardboard	22.1	4.2
Magazines/3rd class mail[c]	2.5	0.5
Newspaper	15.3	2.9
Office paper	25.3	4.8
Phonebook paper	15.3	2.9

[a] The amount of wood used from Table 5 was divided by the weight of a tree (274 lbs.) generated from the theoretical tree model.

[b] This value was determined by multiplying the number of tree equivalents by 0.19 MTCO₂E/tree.

[c] Only 10% of recycled magazines are used in secondary production .[9] In order to compensate for this discrepancy, 90% of virgin wood use for magazine production subtracted from the full value.

The forest carbon sequestration values were compared to existing literature studies to evaluate the validity of the assumptions.[52,53] The first source, published by the United States Department of Agriculture –Forest Service (USDA-FS), indicates that the volume of a loblolly-shortleaf pine stand on forest land 90 years after clearcut harvest in the Southeast is 299.6 m^3/ha.[52] Assuming a value of 123.6 trees/ha (based on an original planting of 500 trees/acre) and a volume of 2.37 m^3/tree for the theoretical tree model, the volume of the stand is 292.9 m^3/ha. This shows that the theoretical tree model predicts forest volume within 2% of the USDA-FS estimates.[52] Additionally, a book published by Thompson (1992), references a calculation attributing 24 trees used per ton of office paper produced, a value consistent with the theoretical tree model results presented in Table 10.[54]

3.4 Dimensional lumber

The recycling emission reduction factor for dimensional lumber, as discussed in the methods section, is not recycled in a closed loop in California. Instead, the recycled lumber is converted into wood chips, dried and used for electricity generation via biomass combustion. The emissions and emission benefits are calculated as follows:

$$DL_e = 19.8 \text{ kg } CO_2/\text{hr} / (3.3 \text{ dry tons/hour} * 2 \text{ green tons}/1 \text{ dry ton})$$
$$= 3 \text{ kg } CO_2E/\text{ton}$$

$$DL_b = (1 \text{ dry ton}/2 \text{ green ton})*(1\text{MWh}/1 \text{ dry ton})*(418.9 \text{ kg } CO_2E/1 \text{ MWh})$$
$$= 209 \text{ kg } CO_2E/\text{ton}$$

$$RERF_{DL} = DL_b - DL_e = 209 \text{ kg } CO_2E/\text{ton} - 3 \text{ kg } CO_2E/\text{ton}$$
$$= 206 \text{ kg } CO_2E/\text{ton} = 0.21 \text{ MTCO}_2E/\text{ton}$$

3.5 Overall Results

The final RERF was determined using equation 5 (section 2.5). A summary of the inputs into the equations the final RERF values are shown in Table 11.

Table 11. Summary of recycling emission reduction factors (RERFs) for each material.

Material	Total Upstream Emission Reductions[a] (a)	Remanufacture Transportation Emissions[a] (b)	Forest Carbon Seq.[a] (c)	Recycling Efficiency (d)	RERF[a] (a-b+c) *d
Aluminum	14.0	0.07	0	0.93	12.9
Steel	1.7	0.16	0	0.98	1.5
Glass	0.2	0.02	0	0.88	0.2
HDPE	1.1	0.09	0	0.77	0.8

PET	2.0	0.15	0	0.77	**1.4**
Corrugated cardboard	1.3	0.10	4.2	0.93	**5.0**
Magazines/3rd class mail	0.1	0.10	0.5	0.67	**0.3**
Newspaper	1.0	0.10	2.9	0.89	**3.4**
Office paper	2.4	0.10	4.8	0.60	**4.3**
Telephone books	1.2	0.10	2.9	0.67	**2.7**
Dimensional lumber	N/A	N/A	N/A	N/A	**0.21**
Mixed Plastics[b]	1.7	0.13	0	0.77	**1.2**

[a] Units are in MTCO$_2$E/ton of material.
[b] The mixed plastics average assumes a mix of 71% PET and 29% HDPE.[27]

3.6 Uncertainty Analysis

The following section gives an overview of the uncertainty associated with each step of the RERF determination. This will not be a quantitative uncertainty assessment due to the nature of many of the data sources used in this study. The qualitative assessment will serve to illuminate particular uncertainties and explain their impact on the overall RERF.

3.6.1 Process and Transportation Emissions:

The two most prevalent sources of error within this section are the reliability of the material life-cycle data and the representativeness of the emission factors to accurately portray the process emissions. The material life-cycle data used in this study[9,10] is relatively old when compared to the timescale technological development. For example, in a related study,[57] the mass of a computer was assigned a value of 70 pounds. As technology has advanced in the past five years, the weight of computer has declined, which would lead to different assumptions about its manufacturing stage in a life-cycle calculation. While most materials in this study do not change technologies as quickly as a computer, the overall data used to generate the emissions from manufacturing may need updating. Because industrial technology usually does not increase the energy inputs, the overall emissions for the upstream energy component of the RERF would more than likely decrease. However, the magnitude of this decrease is not known.

The emission factors used in this study were specific to either California (i.e., goods movement) or the United States (i.e., electricity use). However, in many cases, steps in the material manufacturing process and transportation emissions take place in countries that may have different emission factors. Specifically, the electricity grid may vary from the United States average and the vehicle fleet used in another country may be different. Of these two factors, the electricity

component will play a larger role in the energy emissions because transportation emissions are negligible in comparison to process emissions (Table 6). After evaluating the electricity needs for virgin and recycled production (Supplemental Spreadsheet) of each material, aluminum would be most impacted by a varying electricity emission factor. Assuming the cleanest fuel mix would be all renewable is not likely. Therefore, assume a natural gas source for electricity generation as the cleanest and a coal source as the dirtiest. According to WRI, a coal-fired plant in China (including Hong Kong) generates 910.5 kg CO_2/MWh and a gas fired plant in China emits 387.9 kg CO_2/MWh.[56] In this method, a value of 676 kg CO_2/MWh was used.[20] Applying the gas and coal-sourced electricity generation as a low and high bound, respectively, sets the aluminum electricity requirement between 6.3 and 14.8 MTCO$_2$E/ton of material. The value used in this study (10.6 MTCO$_2$E/ton of material) is the median of the high and low estimate. The other materials did not significantly vary in electricity use between virgin and recycled material production.

3.6.2 Transportation Correction Factor:

The errors associated with these calculations mainly occur due to the lack of understanding in the goods movement process at the international level and the uncertainties that surround the fleet efficiency. In general, a shipping crate is transported, first by truck and/or rail to a port where it is loaded onto a ship and transported to another port where the crate is unloaded and transported via truck and/or rail to its final destination.[57] Each of the five transportation assumptions used in this study take these steps into account (when applicable, Table 4).

An incomplete understanding of the distance travelled during the goods movement process may lead to an underestimation of the transportation emissions associated with each RERF. For example, in the current study, it is assumed that there is an average of 100 truck-miles travelled to get the recycled material to a rail station or port and an average of 100 truck-miles travelled to get the recycled material to its point of remanufacture. Assuming these values were closer to 500 miles in each direction would increase the overall transportation emissions 0.1 MTCO$_2$E/ton of material. This equates in some cases to a large contribution to emissions (e.g. glass, magazines), but in most cases (at an average of 2.0 MTCO$_2$E/ton) it equates to a 5% or less decrease in the overall RERF. Increasing the rail or ocean going vessels miles travelled by 1000 miles increases the overall transportation by 0.02 MTCO$_2$E/ton, which is a negligible amount.

Uncertainties in the fleet efficiency can lead to over or underestimation of the transportation emissions. An efficient, modern fleet can have low emissions, while an old fleet with inefficient energy consumption can have high emissions. A study compared California in-state tractors trucks to drayage vehicles near the ports and found that, on average, the drayage vehicles are slightly less efficient by 3 g CO_2/net ton-mile.[30] This uncertainty has a negligible effect on the overall transportation emission component of the RERF. Because the rail and ocean

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going vessel factors are much smaller, even doubling the emissions under the most extreme conditions increases the transportation emission factor by 2% (assuming an additional 2300 rail-miles) and 7 % (assuming an additional 7000 nautical-miles), respectively (Table 4).

3.6.3 Forest Carbon Sequestration:

The theoretical tree model has many sources of error that can change the overall forest carbon sequestration value. Possible errors include modifications to the growth rate, height, dbh, density and mortality rate. Changing either of these variables in the model would either increase or decrease the amount of carbon sequestered in the theoretical tree. However, because this model is based on a loblolly pine and the assumptions match macroscale approximations,[52] small changes in the above variables would not play a large role in the overall results.

The largest area of uncertainty lies in the choice of the loblolly pine. Although ubiquitous in the Southeast United States, it is not common in other parts of the country. Other pine and fir species are used to produce lumber and paper products. In order to evaluate the range of possible forest carbon sequestration values using other tree species, macroscale growth predications for pines and firs around the country were evaluated using Smith et al (2006).[52] For the comparison, the mean timber volume from Tables A7, A12, A17, A18 A19, A20, A22, A24, A27, A28, A30, A32, A33, A37, A38, A40, A41, and A47 were summed together at year 90 (year 100 was not available for all species) and averaged.[52] The average value between these 18 tables was 318 m^3/ha with a range between 1088 m^3/ha (Douglas Fir, Pacific Northwest, West) and 116 m^3/ha (Ponderosa Pine, Rocky Mountain, South). The difference between the average volume value from Smith et al and this method is 7.7%.[52] Applying the 7.7 % to the theoretical tree model-generated forest carbon sequestration value adds 0.015 $MTCO_2E$/tree onto the 0.19 $MTCO_2E$/tree factor. This would increase the overall forest carbon sequestration for different materials by a maximum of 0.38 $MTCO_2E$/ton of material (e.g. office paper with a value of 25.3 tree equivalents/ton (Table 10)). Additionally, for office paper, this results in a 5% change in the overall RERF (Table 11).

3.7 Comparison to existing studies

The following section evaluates the RERF of each material compared to other studies completed in the literature or by government agencies. Table 12 compares the RERF values generated in this study to the Waste Reduction Model (WARM)[4] developed by the United States Environmental Protection Agency and the Greenhouse Gases Calculator for Waste Management (GGCWM)[5] developed by Environment Canada. The WARM and GGCWM values listed in Table 12 are not relative to other waste alternatives (as described in the background section). Instead, the listed values in Table 12 reflect only the recycling component of each tool.

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The section is designed to verify that the RERFs in this method are consistent with existing literature; in situations when this is not the case, the differences will be evaluated. The differences in RERFs may be due to electricity mix, industrial location, life-cycle boundaries, or other factors.

Table 12. Comparison of RERFs to other recycling studies[a]

Material	This method	WARM[b]	GGCWM[c]
Aluminum	12.9	13.67	8.75
Steel	1.5	1.8	1.07
Glass	0.2	0.28	0.09
HDPE	0.8	1.4	2.06
PET	1.4	1.55	3.29
Corrugated cardboard	5.0	3.11	2.96
Magazines/3rd class mail	0.3	3.07	2.90
Newspaper	3.4	2.8	2.49
Office Paper	4.3	2.85	2.90
Telephone books	2.7	2.66	2.97
Dimensional lumber	0.21	2.46	NA[d]
Mixed Plastics[e]	1.2	1.52	1.63

[a] All units are in $MTCO_2E$/ton of material
[b] WARM = Waste Reduction Model
[c] GGCWM = Greenhouse Gases Calculator for Waste Management
[d] The GGCWM did not report a value for dimensional lumber.[5]
[e] The mixed plastics average assumes a mix of 71% PET and 29% HDPE (Ref. 27).

3.7.1 Inorganic materials

The inorganic materials (e.g. aluminum, steel, etc.) are generally consistent with the WARM and GGCWM models, however, the wood-based organic materials vary in many cases (Table 12). For example, the magazines/3rd class mail category varies by an order of magnitude between this method and WARM.

3.7.1.1 Aluminum

The calculated process and transportations emissions for aluminum were 14.0 $MTCO_2E$/ton (Table 8) in this method and 13.67 $MTCO_2E$/ton in WARM (value after multiplying by the R_{use} variable)[4]. The overestimate of emissions in this method compared to WARM may be due to the nature of the emission factors employed in the study. The GGCWM model uses a Canadian electricity emission factor which is much lower than the United States electricity emission factor, which leads to a lower emission value.[5]

The RERF for aluminum was also compared to other aluminum studies. A recent paper by McMillan and Keoleian indicated that a global average emission factor for

aluminum production in 2005 was 13.3 $MTCO_2E$/ton primary ingot, which is comparable to this method.[7] A study completed in China found that aluminum process emissions were 19.6 $MTCO_2E$/ton for China, which were about 70% higher than the global average of 11.5 $MTCO_2E$/ton (value is dependent on electricity mix).[58] Another study on the Indian aluminum industry indicated that their average emissions are on the order of 20.4 $MTCO_2E$/ton.[59]

3.7.1.2 Steel

The RERF for steel is consistent with the factors from WARM and GGCWM (Table 12). Small discrepancies in the overall values can be attributed to the emission factors used and the electricity mix used in this method. An evaluation of the steel-making capacity in Russia indicates that it requires about 3.4 $MTCO_2E$/ton of steel production.[60] While this value is higher than the RERF, the discrepancy may be due to higher emission factors for electricity use and different, less efficient steel-making mechanisms in Russia. A study by Gorgolewski (2006) indicates that 600 kg of coal/tonne is avoided by recycling steel (544 kg/ton).[61] Using an aggregate emission factor for coal,[22] this equates to an emission reduction of 1.1 $MTCO_2$/ton.[61]

3.7.1.3 Glass

The RERF generated in this method is consistent with WARM and GGCWM (Table 12). A paper that evaluated the energy inputs needed to make a 200 g glass jar indicated that it took about 73 g CO_2E/200 g glass jar. Assuming there are 4536 glass jars in a short ton, the total manufacturing emissions are 0.33 $MTCO_2E$/ton.[62] This is comparable to the results from this method for the emissions associated with producing a ton of glass from virgin materials (Table 8).

3.7.1.4 High Density Polyethylene (HDPE)

The RERF for HDPE is lower by about a factor of 2 when compared to the WARM and GGCWM studies, respectively (Table 12). This rather large discrepancy may have occurred due to the data source availability. The data used in this method for the energy process and transportation emissions for virgin production is consistent with a study completed by Franklin and Associates assigns a value of 1.34 $MTCO_2E$/ton of material to the emissions from virgin HDPE resin production (for comparison, see Table 8, 1.6 $MTCO_2E$/ton of material).[63] The results from this method are also consistent with a study completed by Boustead.[64] This study, funded by PlasticsEurope, indicated that the GHG emissions associated with producing one ton HDPE resin was 1.45 $MTCO_2E$.[64] Other studies by PlasticsEurope indicate the emissions for HDPE are higher as greater production is involved. For example, the production of HDPE bottles is 2.36 $MTCO_2E$/ton, indicating that the boundaries assumed in this method and WARM may vary.[4]

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3.7.1.5 Polyethylene Terephthalate (PET)

The PET RERF is consistent with WARM, but underestimated by a factor 2 when compared to GGCWM (Table 12). The study from FAL (2007)[65] indicates that emissions for PET are 2.3 $MTCO_2E$/ton for virgin material production, which is consistent with this method (Table 8, 2.4 $MTCO_2E$/ton of material). The PlasticsEurope study uses an average of PET amorphous (2.54 $MTCO_2E$/ton) and PET bottle-grade (2.63 $MTCO_2E$/ton) resin to generate a total of 2.50 $MTCO_2E$/ton, which is slightly higher.[65,66] When compared to PET bottle production, the emissions are 3.72 $MTCO_2E$.[67]

3.7.2 Wood-based organic materials

Unlike the materials discussed above, the wood-based organic materials RERF include a forest carbon sequestration component. The forest carbon sequestration factor accounts for the incremental carbon sequestered in a tree that would not have occurred if the tree would have been harvested. The comparisons below reflect the existing literature for wood-based organic materials.

3.7.2.1 Corrugated cardboard

The RERF for corrugated cardboard is about 1.7 times higher in this method compared to WARM and GGCWM (Table 12). The discrepancy occurs in the manufacturing stage emissions (a difference of ~1.3 $MTCO_2E$/ton) and the forest carbon sequestration (a difference of ~1.2 $MTCO_2E$). According to WARM,[4] the manufacturing stage emissions for corrugated cardboard is ~ 0. This is in contrast to this method (Table 8) which calculates an emissions benefit of 1.3 $MTCO_2E$/ton. Additional information on this issue can be viewed in the Supplemental Spreadsheet. The manufacturing emissions from corrugated cardboard were also calculated by the Paper Task Force (2002).[36] In this study,[36] the manufacturing emissions were 1.4 $MTCO_2E$ (relative to recycling), which is consistent with this method.

WARM assigns a forest carbon sequestration value for corrugated cardboard of 3.0 $MTCO_2E$/ton.[4] While the WARM value is slightly different than this method (Table 12), the method used to calculate the forest carbon sequestration is markedly different. While this method employs a microscale, single tree approach, the USEPA(2006)[4] study uses a macroscale, stock change approach that is consistent with other methods utilized at the national level.[68]

3.7.2.2 Magazines/3rd Class Mail

The RERF for magazines/3rd class mail was only 0.3 $MTCO_2E$/ton in this method, compared to a much higher values in the WARM model (Table 12). The discrepancy in values is mainly due to the forest carbon sequestration factor. According to a manuscript by USEPA,[9] magazines only use 10% of recycled

material in recycled magazine paper. The remaining 90% comes from primary groundwood fiber. For this reason, 90% of the weight of virgin wood (Table 5) for magazines/3rd class mail was subtracted out of the forest carbon sequestration factor. Because of the different methods used by WARM[4] in their determination of the forest carbon sequestration factor, this method has a much lower value for this product.

3.7.2.3 Newspaper

The newspaper RERF is slightly higher in this method compared to WARM and GGCWM (Table 12). The manufacturing emissions in the WARM model are 0.7 $MTCO_2E$[4] compared to 1.0 $MTCO_2E$ in this method (Table 8). Research from the Paper Task Force (2002)[36] indicates that the upstream energy emissions are 2.7 $MTCO_2E$/ton. Additionally, the forest carbon sequestration value is also higher in this method than WARM.[4] The tree equivalents used in this method are consistent with a calculation performed for *Recycled Papers: The Essential Guide.*[53]

3.7.2.4 Office Paper

The office paper RERF in this method is higher than WARM and GGCWM (Table 11). The forest carbon sequestration factor is consistent with WARM,[4] but the manufacturing emissions are much higher than WARM (2.4 $MTCO_2E$/ton in this method vs. -0.20 $MTCO_2E$/ton in WARM). The reason for this large discrepancy may be due to an added assumption that was not made in this study but assumed in WARM.[4]

Two previous studies have evaluated the upstream energy benefits of recycling office paper. The Paper Task Force[36] determined the upstream energy emissions from recycling to be 1.36 $MTCO_2E$/ton, which is an intermediate value between WARM and this method. Additionally, Counsell and Allwood[8] calculated a value of 4.4 $MTCO_2E$/ton. This value was determined by summing together the avoided emissions associated with forestry, pulping and landfilling. After completing this review, it is evident the upstream emission benefits from recycling office paper have a wide range. The results range from positive emissions to over 4 $MTCO_2E$/ton of benefits.

3.7.2.5 Telephone Books

The RERF value for this method is consistent with existing studies (Table 12). Both the upstream energy and forest carbon sequestration component are similar to WARM.[4]

3.7.2.6 Dimensional Lumber

The RERF value for this method is not similar to the WARM study (Table 12). The difference is due to the methods used to determine the value. In the WARM study,

it was assumed that recycled dimensional lumber was remanufactured into more lumber while in this method, it is assumed that lumber is chipped and used at biomass facility.

4. SUMMARY

This method estimates recycling emission reduction factors for various recyclable materials. The recycling factors are based on the emission benefit of using recycled material over virgin inputs in the manufacturing stage, forest carbon sequestration, the transportation associated with moving the recycled material to the point of remanufacturing and the recycling efficiency. The data sources relied upon in the study are well-documented and the methods used are clearly defined. This method does not evaluate the associated avoided landfill methane (CH_4) benefits of recycling. Fugitive CH_4 emissions are accounted for separately as part of the California greenhouse gas inventory.[17]

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EXHIBIT "G"

CANADIAN ASSOCIATION OF PETROLEUM PRODUCERS

GUIDE

Occupational Health and Safety of Hydrogen Sulphide (H₂S)

March 2003

The Canadian Association of Petroleum Producers (CAPP) represents 140 companies that explore for, develop and produce natural gas, natural gas liquids, crude oil, oil sands, and elemental sulphur throughout Canada. CAPP member companies produce over 97 per cent of Canada's natural gas and crude oil. CAPP also has 125 associate members that provide a wide range of services that support the upstream crude oil and natural gas industry. Together, these members and associate members are an important part of a $60-billion-a-year national industry that affects the livelihoods of more than half a million Canadians..

Review by July 2008

Disclaimer

This publication was prepared for the Canadian Association of Petroleum Producers (CAPP) by CAPP's Industrial Hygiene and Safety Committee. While it is believed that the information contained herein is reliable under the conditions and subject to the limitations set out, CAPP does not guarantee its accuracy. The use of this report or any information contained will be at the user's sole risk, regardless of any fault or negligence of CAPP.

Overview

The Canadian Association of Petroleum Producers (CAPP) have developed this Hydrogen Sulphide (H_2S) Guideline to assist member companies in the development of their Codes of Practice. It is specifically for upstream petroleum industry companies that do not have occupational health and safety expertise in their employ. This Guideline outlines the procedures for handling, monitoring, training, labeling and emergency response to petroleum products containing H_2S.

Its companion, Guideline: Occupational Health and Safety of Light Hydrocarbons, should be referenced and implemented where necessary (see CAPP Pub 1999-0002 and 1995-0011). It outlines the procedures for handling, monitoring, training, labeling and emergency response to methane, ethane, butane isomers and propane.

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Project Scope

Hydrogen sulphide (H_2S) is a common petroleum contaminant. It may be present as a gas or may be dissolved in produced water, crude oil or natural gas condensate. Hydrocarbons contaminated with H_2S are called "sour".

For health and safety purposes, all facilities processing hydrocarbons contaminated with any concentration of H_2S should be evaluated for the potential of worker overexposure. If the potential exists, then a Code of Practice should be implemented. In addition, implementing the Canadian Association of Petroleum Producers' Light Hydrocarbon Code of Practice should be considered. The Light Hydrocarbon Code of Practice recommends handling and monitoring procedures for sweet methane, ethane, butane and propane.

1   Hazards of H_2S

1.1   Acute Health Hazards

Hydrogen sulphide is extremely toxic at very low concentrations. More than 100 parts of H_2S per million parts of air (100 ppm) is Immediately Dangerous to Life and Health (IDLH) for exposures of 30 minutes or more. Exposure to more than 10 ppm for eight hours, or more than 15 ppm for 15 minutes, may irritate the eyes, nose and throat.

Hydrogen sulphide has a rotten egg odour. This odour cannot be used to detect H_2S because people rapidly lose their sense of smell when H_2S level sa re above 100 ppm.

Table One summarizes the toxic effects that result from inhaling various concentrations of H_2S.

1.2   Long Term Health Hazards

Human studies have found no direct link between exposure to low H_2S concentrations (less than 10 ppm) and long term health effects. Some research studies have suggested that low level health effects can be produced at hydrogen sulphide concentrations down to 1 ppm. However, these results have not been confirmed to date. One animal study has found some evidence of neurological symptoms such as memory loss after long term exposure to 50 ppm H_2S but this finding has not been confirmed by other studies.

Table 1-1: Health Effects from Inhaling H_2S

Concentrations	Effect
10 ppm or less	No known short term effects from 8 hr exposures.
20 – 50 ppm	Eye, nose, throat and lung irritation.
50 – 100 ppm	Marked eye, nose, throat and lung irritation.
100 – 150 ppm	Severe eye, nose, throat and lung irritation. Loss of smell. Exposure duration of 8 hours or more may be fatal.
200 – 300 ppm	Headaches, drowsiness. Prolonged exposures of several hours may cause the lungs to fill with fluids.
300 – 500 ppm	May cause unconsciousness and death in 1 to 4 hours.
500 – 700 ppm	Knockdown (may be fatal) with 1 hour exposure.
Greater than 700 ppm	Immediate knockdown (may be fatal).

1.3 Physical Properties

Pure hydrogen sulphide is slightly heavier than air and may collect in low spots under certain conditions. Hydrogen sulphide and hydrocarbon mixtures may act differently than pure H_2S. When H_2S is mixed with some light hydrocarbons such as methane, the mixture can be lighter than air. When mixed with heavier hydrocarbons, such as NGL, the mixture is much heavier than air. It is almost impossible to predict where H_2S may concentrate in outdoor areas or buildings. It is important to monitor for H_2S in all locations in outdoor areas or buildings.

H_2S is soluble in water and hydrocarbons. Any H_2S gas that comes out of solution will collect in the head spaces of tanks, pipes and vessels containing sour liquids, liquid sulfur and solid sulfur. It is possible for H_2S to collect in confined areas in concentrations far exceeding those found in the liquid. For example, the head space of a tank may exceed the Occupational Exposure Limit even though it may contain oil with as little as 0.5 ppm H_2S. In some conditions, the H_2S concentrations in the head space may exceed those immediately dangerous to life and health (IDLH). See Appendix A for more information on this potentially dangerous condition.

Large spills or releases of sour liquids may also release hazardous concentrations of H_2S.

Pure hydrogen sulphide is flammable in air at 40,000 ppm (4 per cent) or higher.

2   Occupational Exposure Limits

Occupational Exposure Limits are set by provincial occupational health and safety agencies. Alberta's Occupational Exposure Limits (OELs) are listed in the Chemical Hazards Regulation. British Columbia and Saskatchewan have developed their own exposure limits. Manitoba follows with exposure limits recommended by the American Conference of Governmental Industrial Hygienist (ACHIH). Table Two below summarizes the occupational exposure limits for H_2S.

Table 2-1: Occupational Exposure Limits for H_2S

	8 hour TWA[1] (ppm)	15 STEL[2] (ppm)	Ceiling[3] (ppm)
Alberta	10	-	15
British Columbia	-	-	10
Saskatchewan	10	15	-
ACGIH TLV[4]	5	-	-

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[1] 8 hour TWA – Time Weighted Average. The average exposure based on an eight hour exposure period.

[2] 15 STEL – Short Term Exposure Limit. The average exposure based on a 15 minute exposure period. No more than four STEL are permitted during an eight hour shift and the 8 hour TWA can not be exceeded.

[3] Ceiling – The maximum concentration to which a worker can be exposed to even instantaneously.

[4] The American Conference of Governmental Industrial Hyienists recommends occupational exposure limits called Threshold Limit Values (TLVs). Although widely referenced, they are recommended values only except where formally adopted into legislation.

3   Hydrogen Sulphide Sources

The following table should be used as a guide to operations where high hydrogen sulphide exposures may be expected. However, it is not comprehensive. A risk assessment of the work operation should be performed, taking into account the following:

- H_2S content of the process stream;
- previous exposure monitoring results;
- operation factors (e.g., purging, degassing, temperature/pressure of process stream), and;
- ventilation.

Table 3-1: Examples of Critical H_2S Tasks

Task	H_2S Monitors Required	SCBA/SABA Required
Well maintenance (valve, pump jack servicing, etc.)	yes	no
Pigging	yes	yes
Breaking equipment integrity or when > 10 ppm H_2S in air	yes	yes
Maintenance on equipment without breaking integrity	yes	no
Filter changes	yes	yes
Entering compressor basements	yes	yes
Responding to H_2S alarms	yes	yes
Sampling with open containers	yes	yes
Sampling with closed containers	yes	no
Gauging tanks	yes	yes
Maintenance on purged equipment	no	no
Entering dikes/fire walls	yes	no
Routine operations	yes	no

Task	H₂S Monitors Required	SCBA/SABA Required
General trucking sour fluids	yes	no
Uncoupling vent lines	yes	yes
Uncoupling load lines	yes	no
Sulphur truck loading with degassing without degassing	yes yes	no yes
Sulphur rail car loading	yes	yes

4   Detection

H₂S detection should be conducted using chemical sensing instruments or detector tubes. Operators should be aware of the potential limitations and interference associated with the use of the equipment.

4.1   Chemical Sensors

Chemical sensors are the superior and recommended method of H₂S monitoring. There are three types: personal, hand held and remote monitors. All provide accurate and reliable readings, only if properly calibrated and maintained. They should be calibrated at least once per month, or as recommended by the manufacturer. Calibration should be performed at the temperature at which the instruments will be used. Calibration at room temperature for use in cold conditions can cause inaccurate readings.

Workers carry personal monitors. They provide continuous readings and sound an alarm if H₂S levels exceed 10 ppm or any other predetermined concentration.

Remote sensors are permanent fixed devices suitable for installations like gas plants or oil batteries. Remote sensors also continuously monitor H₂S concentrations and sound an alarm at 10 ppm H₂S.

All chemical sensors have a response time from when the monitor is placed iin an H₂S atmosphere to when the sensor reaches the actual reading. Some sensors may take up to one minute to respond to H₂S concentrations of 10 ppm. However, in atmospheres exceeding 100 ppm, the response time to the alarm concentration (10 ppm) is almost instantaneous. Operation of sensors at temperatures below –20 degrees Centigrade may cause lengthened response times.

Carbon monoxide and other gases may cause interference with H₂S readings. The interference of the instrument being used should be known.

4.2   Detector Tubes

Detector tubes detect and provide a rough measure of H₂S concentrations. Detector tubes do not provide continuous monitoring or sound an alarm. Readings may take up to one minute. Respirators may not be required when detector tubes are used in low risk situations such as sampling process streams. Every situation should be evaluated to determine the possibility of exceeding the applicable occupational exposure limit.

5   Monitoring

All areas where H_2S is present and may exceed 10 ppm must be checked to ensure H_2S concentrations are below 10 ppm. Concentrations above 10 ppm require communication with other personnel to warn of an H_2S hazard and to ensure that further testing is performed. Further testing shall be conducted while wearing pressure-demand self-contained breathing apparatus (SCBA) or supplied air-breathing apparatus (SABA).

All personal and remote monitors shall be set to alarm at 10 ppm. Consideration should be given to wearing personal monitors in all areas where H_2S may be encountered, except where remote sensing is present. Consideration should be given to supplement remote sensing with personal monitors if the hazard is deemed excessive (i.e., very high H_2S).

Personal monitors shall be maintained and calibrated by qualified personnel according to manufacturer's recommendations as a minimum. Remote monitors shall be tested and calibrated according to manufacturer's recommendations or at least quarterly.

6   Personal Protective Equipment

Respiratory protection is required when entering areas where:

- H_2S concentrations are above 10 ppm;
- there is any indication of equipment failure or product leak; or
- entering a confined space containing sour liquids.

The respiratory protection shall be:

- a full face positive pressure self contained breathing apparatus (SCBA); or
- a full face positive pressure supplied air breathing apparatus (SABA) equipped with a 5 minute escape air bottle

Backup personnel are required when entering an IDLH atmosphere of greater than 100 ppm H_2S. Backup personnel should be fully trained in rescue.

7 Training

All workers, prior to entering an area where H_2S is present or may be encountered, shall:

- receive orientation on the site rules and procedures;
- receive rescue and evacuation procedures; and
- hold a current H_2S Alive certificate or equivalent training.

At least one work crew member must hold a current First Aid certificate.

8   Emergency Response

8.1   Pre-Job Planning

Before starting a job, the following should be reviewed with personnel on the site:

1) H_2S hazards and where they may be found;
2) backup personnel requirements;
3) safety watch requirements;
4) muster point location;
5) respirator locations;
6) alarms; and,
7) communication procedures

8.2   First Aid

First aid can only begin after the rescue personnel have left the H_2S area, sounded the alarm, donned breathing apparatus, and brought the victim to a safe area.

Mouth to mouth or rescue breathing is a quick and effective technique that should be used until qualified medical help arrives on the scene.

Only qualified personnel may use mechanical resuscitators or oxygen.

8.3   Rescue

There are seven steps to take during an H_2S emergency.

Step One: Evacuate immediately

An H_2S alarm indicates that there may be hazardous concentrations in the building or area. Get to a safe new area immediately by moving upwind or crosswind from the release. Move to higher ground in possible.

Step Two: Sound the alarm

Immediately notify someone that there is an H_2S release, relay any information you may have and that you may require assistance.

Step Three: Assess the situation

Do a head count and consider other hazards.

Step Four: Protect rescue personnel

Put on SCBA/SABA to protect rescue personnel. If necessary, shut down the plant.

Step Five: Rescue victim

Start by ventilating the building with fans or by opening all doors. If safe, you may perform the rescue by yourself with backup or with assistance. Enter the area and remove the victim to fresh air (upwind if possible).

Step Six: Revive victim

Apply artificial respiration or CPR on the victim until the victim revives or until help arrives.

Only qualified personnel may use mechanical resuscitators or oxygen.

Step Seven: Get medical aid

All H_2S victims require medical attention. Even if they revive quickly, there is still a possibility that the lungs may collect fluid some hours after exposure. Arrange a transport of the victim to medical aid and provide the necessary information to Emergency Medical Services.

9 Signage and Product Labels

9.1 Signage

All facilities and sites where there is H₂S present shall have suitable signs at the entrance warning of the presence of poisonous gas (ERCB Reg. Sec. 7.070).

9.2 Product Labels

Table 9-1: WHMIS Supplier and Workspace Label Specifications

Product	WHMIS Classification	PPE Symbols
Sour Natural Gas	Class A: Compressed Gas Class B, Div. 1: Flammable Gas Class D, Div. 1, Sub-Div. A: Very toxic material. Immediate and Serious Effects.	SCBA/SABA[5]
Sour Condensate	Class B, Div. 2: Flammable Liquids Class D, Div. 1, Sub-Div. A: Very toxic material. Immediate and Serious Effects.	SCBA/SABA Gloves Apron or skin protection
Sour Crude Oil	Class B, Div. 2: Flammable Liquids Class D, Div.1, Sub-Div. A: Very toxic material. Immediate and Serious Effects. Class D, Div. 2, Sub-Div A: Material cuasing other toxic effects. Very toxic material.	SCBA/SABA Gloves Apron or skin protection
Sour Produced Water	Class D, Div. 1, Sub-Div. A: Very toxic material. Immediate and Serious Effects. If oil mix: Class B, Div. 2: Flammable Liquids	SCBA Gloves Apron or skin protection

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[5] SCBA/SABA: Self Contained Breathing Apparatus/Supplied Air Breathing Apparatus

Appendix A   **Hydrogen Sulphide in Residual Fuel Oil**
and
Storage Tank Vapour Space

3847

Summary Report

Hydrogen Sulfide in Residual Fuel Oil and Storage Tank Vapor Space

DONALD J. SLACK

Texaco Refining and Marketing, Inc., 1111 Rusk Street, Houston, TX 77002

Measurements of hydrogen sulfide in liquid petroleum residual fuel oil and in the vapor space of residual fuel oil storage tanks and sample containers were taken to determine if a useful correlation existed between the liquid and vapor phase hydrogen sulfide concentrations. As a rough approximation, a vapor phase to liquid phase correlation of about 50:1 was found. The correlation showed considerable variance which increased with increasing hydrogen sulfide concentrations. The correlation reveals that liquid phase analysis of hydrogen sulfide in residual fuels can be used to identify fuel oil products which require occupational health controls.

Method

Residual petroleum fuel oils such as bunker fuel oil, #6 fuel oil, fuel oil C and marine fuel oil can contain hydrogen sulfide. Measurement of hydrogen sulfide in the liquid (ppm by weight) and in the vapor space (ppm by volume) were taken to determine what correlation existed between the liquid phase concentration and the concentration in the vapor phase of the storage compartment.

Hydrogen sulfide in the liquid phase of petroleum residual fuel oil was measured using a modification of Mobil Analytical Method 1404.[1] Liquid samples were collected from petroleum storage tanks and ship and barge holds. Each liquid sample was paired with a sample of hydrogen sulfide which was taken simultaneously from the vapor space of the liquid storage compartment or from the headspace of the sample container. Fifty-five pairs of samples were collected.

The vapor space measurements were collected by Draeger detector tubes (National Draeger, Inc., Pittsburgh, Pa.) which were lowered 0.3 m (1.0 ft) into the storage compartment vapor space or inserted into the sample container headspace. While the liquid temperature was typically 60°C (140°F), the vapor space temperatures at the point of measurement were near ambient temperatures.

Discussion

The paired samples were evaluated by linear regression. Paired data for liquid phase concentrations between analytical detection limits and 14 ppm were used. The best fit relationship was found to be a power function of the form $y = 30(x)^{1.2}$, where y is the vapor space concentration (ppm by volume) and x is the liquid phase concentration (ppm by weight). As a rough approximation, this liquid phase to vapor phase correlation can be regarded as a 50:1 linear relationship.

The coefficient of determination of the best fit curve is 0.88. The predictive value of the relationship is limited severely above 8 ppm liquid phase hydrogen sulfide concentration because of the considerable variation in the data.
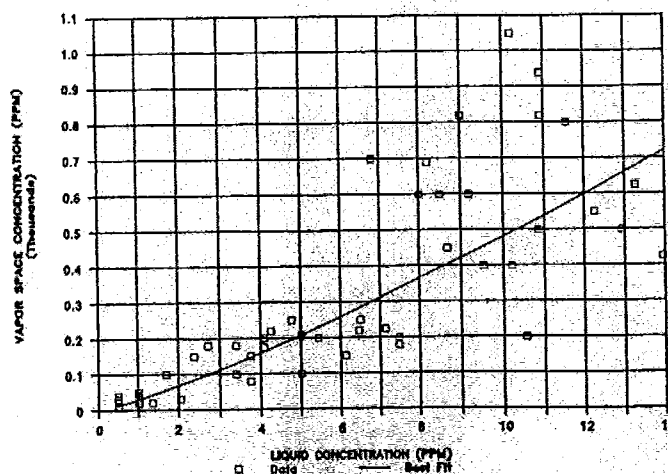

Figure 1—Correlation of liquid and vapor phase hydrogen sulfide concentrations in fuel oil.

TABLE I
Decrease in Liquid and Vapor Phase Hydrogen Sulfide with Time
(Tank 20D-46)

	Vapor Phase (ppm by volume)	Liquid Phase (ppm by weight)
Day 1	940	10.90
Day 2	816	10.60
Day 3	695	7.50
Day 6	425	5.40
Day 7	265	3.74

TABLE II
Decrease in Average Vapor Phase Hydrogen Sulfide (ppm by volume) Resulting from a Single Product Transfer

	Shipping Tank	Receiving Barge
Case 1	1190	124
Case 2	600	104
Case 3	600	200
Case 4	750	137

When plotted (Figure 1), increased variation in the relationship at higher concentrations of hydrogen sulfide is evident; variation increases significantly above 8 ppm liquid phase hydrogen sulfide concentrations.

As would be expected, hydrogen sulfide concentrations in both the liquid and vapor phases decreased over time where residual fuel oils were stored in vented storage tanks (Table I). Product transfer and agitation of the liquid accelerated the decrease in hydrogen sulfide concentration in both the vapor phase (Table II) and the liquid phase. The liquid phase concentration of hydrogen sulfide dropped from 6.80 to 0.68 ppm, and the vapor phase concentration dropped from 150.0 to 40.0 ppm as a result of one typical product transfer.

Hydrogen sulfide concentrations in the liquid were somewhat higher in samples taken from liquid near the bottom of the tank compared with liquid samples taken from the surface. For example, hydrogen sulfide liquid phase concentrations were found to be 4.08, 4.25 and 5.44 ppm, respectively, in samples from the top, middle and bottom of a barge

compartment. These values are typical of those found in other storage tanks.

Hydrogen sulfide concentrations in the vapor space were essentially homogeneous from the liquid level to the top of the storage compartment. Vapor space concentrations, however, were found to vary considerably at hatches or vent openings unless measurements were made at least 0.3 m (1.0 ft) below the top of the gauge or hatch openings.

Conclusion

Very low (several ppm) liquid phase concentrations of hydrogen sulfide in residual fuel oil may produce high vapor phase hydrogen sulfide concentrations (hundreds of ppm). Consequently, occupational health controls may be required when handling these products or when entering confined spaces involving these products. Liquid phase hydrogen sulfide concentrations above 8 ppm by weight can produce atmospheres immediately dangerous to life or health (IDLH) in residual fuel oil storage tanks and ship and barge holds. The correlation between liquid and vapor phase hydrogen sulfide concentrations cannot be used as a substitute for workplace monitoring of exposure, but it can be a useful guide for identifying residual fuels containing significant amounts of hydrogen sulfide.

An effective hazard communication program is needed to warn employees of the hazards of hydrogen sulfide in residual petroleum fuels and to advise of proper precautions for handling these materials. Residual fuel oil storage compartments must be tested for hydrogen sulfide in the vapor space in order to permit entry or select respiratory protection for employees. Transfer and handling operations should be monitored in order to evaluate the need for occupational health controls, such as engineering controls, special work practices or respiratory protection.

The publication of other studies showing the relationship of hydrogen sulfide vapor phase to liquid phase in petroleum streams is encouraged.

References

1. Mobil Technical Service Laboratories: Tentative Mobil Analytical Method 1404. Mobil Technical Center, Attn: Ms. Gwen Johnson, Princeton, N.J., September 27, 1984. (personal correspondence).
29 May 1987; Revised 22 December 1987

Dangerous Properties of Industrial Materials

Seventh Edition

Volume III

N. IRVING SAX

and

RICHARD J. LEWIS, SR.

HIC500   HYDROGEN SULFIDE

which it is flammable in air. Very little data are available on possible chronic effects of this material, but it is logical to assume that when the concentration of this gas is low enough to avoid the irritant effects, only the systemic effects will be noticeable.

Dangerous fire hazard when exposed to heat or flame; will react vigorously with powerful oxidizing agents, such as H_2O_2; HNO_3. Dangerous; forms explosive mixtures with air; keep away from heat and open flame. See also SELENIUM COMPOUNDS and HYDRIDES.

HIC500   HR: 3
HYDROGEN SULFIDE
CAS: 7783-06-4   NIOSH: MX 1225000
DOT: 1053
mf: H_2S mw: 34.08

PROP: Colorless, flammable gas; offensive odor. Mp: −85.5°, bp: −60.4°, lel: 4%, uel: 46%, autoign temp: 500°F, d: 1.539 g/L @ 0°, vap press: 20 atm @ 25.5°, vap d: 1.189.

SYNS:

ACIDE SULFHYDRIQUE (FRENCH)	SCHWEFELWASSERSTOFF (GERMAN)
HYDROGENE SULFURE (FRENCH)	
HYDROGEN SULFURIC ACID	SIARKOWODOR (POLISH)
IDROGENO SOLFORATO (ITALIAN)	STINK DAMP
	SULFURETED HYDROGEN
RCRA WASTE NUMBER U135	SULFUR HYDRIDE
	ZWAVELWATERSTOF (DUTCH)

TOXICITY DATA: CODEN:
ihl-hmn LCLo:600 ppm/   29ZWAE -,207,68
  30M
ihl-man LDLo:5700 μg/kg: AMPMAR 44,483,83
  CNS,PUL
ihl-hmn LCLo:800 ppm/5M   TABIA2 3,231,33
ihl-rat LC50:444 ppm   LacHB# 09JUN78
ihl-mus LC50:673 ppm/1H   NTIS** PB214-270
ihl-mam LCLo:800 ppm/   AEPPAE 138,65,28
  5M

EPA Extremely Hazardous Substances List. Reported in EPA TSCA Inventory.

OSHA PEL: CL 20 ppm; Pk 50/10M
ACGIH TLV: TWA 10 ppm; STEL 15 ppm
NIOSH REL: (Hydrogen Sulfide) CL 15 mg/m³/10M

DOT Classification: Flammable Gas; Label: Poison Gas and Flammable Gas.

THR: A human poison by inhalation. A severe irritant to eyes and mucous membranes. An asphyxiant. Human systemic effects by inhalation: coma, chronic pulmonary edema. Low concentrations of 20-150 ppm cause irritation of the eyes, slightly higher concentrations may cause irritation of the upper respiratory tract, and if exposure is prolonged, pulmonary edema may result. The irritant action has been explained on the basis that H_2S combines with the alkali present in moist surface tissues to form sodium

sulfide, a caustic. With higher concentration the action of the gas on the nervous system becomes more prominent. A 30 minute exposure to 500 ppm results in headache, dizziness, excitement, staggering gait, diarrhea and dysuria, followed sometimes by bronchitis or bronchopneumonia.

The action of small amounts on the nervous system is one of depression; in larger amounts, it stimulates, and with very high amounts the respiratory center is paralyzed. Exposures of 800-1000 ppm may be fatal in 30 minutes, and high concentrations are instantly fatal. Fatal hydrogen sulfide poisoning may occur even more rapidly than that following exposure to a similar concentration of HCN. H_2S does not combine with the hemoglobin of the blood; its asphyxiant action is due to paralysis of the respiratory center. With repeated exposures to low concentrations, conjunctivitis, photophobia, corneal bullae, tearing, pain and blurred vision are the commonest findings. High concentrations may cause rhinitis, bronchitis, and occasionally pulmonary edema. Exposure to very high concentrations results in immediate death. Chronic poisoning results in headache, inflammation of the conjunctivae and eyelids, digestive disturbances, weight loss and general debility. It is a common air contaminant.

It is an insidious poison since sense of smell may be fatigued. The odor and irritating effects do not offer a dependable warning to workers who may be exposed to gradually increasing amounts and therefore become used to it.

Very dangerous fire hazard when exposed to heat, flame, or oxidizers. Moderately explosive when exposed to heat or flame. Explodes on contact with oxygen difluoride; nitrogen trichloride; bromine pentafluoride; chlorine trifluoride; dichlorine oxide; silver fulminate. Potentially explosive reaction with copper + oxygen. Explosive reaction when heated with perchloryl fluoride (above 100°C); oxygen (above 280°C). Reacts with 4-bromobenzenediazonium chloride to form an explosive product.

Ignites on contact with metal oxides (e.g., barium peroxide; chromium trioxide; copper oxide; lead dioxide; manganese dioxide; nickel oxide; silver(I) oxide; silver(II) oxide; sodium peroxide; thallium(III) oxide; mercury oxide; calcium oxide; nickel oxide); oxidants (e.g., silver bromate; heptasilver nitrate octaoxide; dibismuth dichromium nona oxide; mercury(I) bromate; lead(II) hypochlorite; copper chromate; fluorine; nitric acid; sodium peroxide; lead(IV) oxide); rust; soda-lime + air. Reacts violently with NH_3; NF_3; p-bromobenzenediazonium chloride; OF_2; F_2; Cu; ClO; BrF_5; acetaldehyde; (BaO + Hg_2O + air); (BaO + NiO + air); hydrated iron oxide; phenyl diazonium chloride; (NaOH + CaO + air). Incandescent reaction with chromium trioxide. Vigorous reaction with metal powders (e.g., copper; tungsten). When heated to decomposition it emits highly toxic fumes of SO_x. To fight fire, stop flow of gas. For further information, see Vol. 3, No. 4 of *DPIM Report*.

EXHIBIT "H"

Incident Report

2011-1131690 -000

Kern County

Basic	
Alarm Date and Time	11:29:02 Wednesday, October 12, 2011
Arrival Time	11:43:07
Controlled Date and Time	
Last Unit Cleared Date and Time	14:10:03 Wednesday, October 12, 2011
Response Time	0:14:05
Priority Response	Yes
Completed	Yes
Reviewed	Yes
Release to Public	Yes
Fire Department Station	K51
Shift	B
Incident Type	355 -- Confined space rescue
Initial Dispatch Code	RX
Aid Given or Received	N - None
Alarms	1
Action Taken 1	22 - Rescue, remove from harm
Action Taken 2	32 - Provide basic life support (BLS) KCFD
Action Taken 3	55 - Establish safe area
Casualties	No
EMS Provided	Yes
Apparatus - Suppression	7
Personnel - Suppression Personnel	19
Property Use	919 - Dump, sanitary landfill
Location Type	Address
Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241
Latitude	17.2706096
Longitude	-619.35831

Person Involved - Addis, Chuck	
Involvement Code	REP
Last Name	Addis
First Name	Chuck
Business Name	A & B Harvesting
Street Address	
Phone	8058386585

Person Involved - Avalos, Enedino	
Involvement Code	MGR
Last Name	Avalos
First Name	Enedino
Business Name	Community Recycling
Street Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241
Phone	6613437425

Person Involved - Baldwin, Robert	
Involvement Code	PM

	Narratives

KC Environmental Health personnel arrived on scene after all pts had been transported to the hospital. They used monitoring equipment to measure the IDLH atmosphere in the drain pipe. The decomposing material at the bottom of the drain pipe produced gases that were highly concentrated in the confined space of the pipe.

An AAR was conducted.

Pt information was given to ECC on 10-13-2011 @ 0050 Hrs, per AP104.60

Narrative Name	CO 51
Narrative Type	Incident
Narrative Date	08:22:34 Thursday, October 13, 2011
Author	K0643 - Crider, Martin R
Author Rank	FC
Author Assignment	1
Narrative Text	E51'S CREW ASSISTED W/ THE RESCUE OPERATION. ALL MEMBERS OF E51'S CREW USED AN SCBA DURING THE RESCUE OPERATION. MC 0643
Narrative Name	Release to Public
Narrative Type	Incident
Narrative Date	08:57:09 Thursday, October 13, 2011
Author	K0604 - Weston, Doreen A
Author Rank	3179
Author Assignment	0
Narrative Text	Report released to US Chemical Safety And Hazard Investigation Board on 10/13/2011. Report released to Cal OSHA on 10/17/2011.

End of Report

	Narratives
Narrative Date	17:34:45 Wednesday, October 12, 2011
Author	K0746 - Duncan, Aaron S
Author Rank	FC
Author Assignment	1
Narrative Text	ADVISED IC TO RESPOND ENVIRONMENTAL HEALTH AND WAS CANCELLED ENROUTE.
Narrative Name	Co52
Narrative Type	Incident
Narrative Date	17:50:12 Wednesday, October 12, 2011
Author	K0623 - Linville, Kain M
Author Rank	FC
Author Assignment	1
Narrative Text	on scene we supported ops with manpower, pt care, engineer attempted to monitor air (monitor failed to operate), brought air changer to scene, pts removed rapidly and air changer not set up due to rescue at hand. Assisted environmental health with additional monitoring of area interior and exterior.
Narrative Name	Co 54
Narrative Type	Incident
Narrative Date	22:52:22 Wednesday, October 12, 2011
Author	K0747 - Knaggs, Jason E
Author Rank	FC
Author Assignment	1
Narrative Text	E54 was the first unit to arrive on scene at a reported rescue for a man down in the bottom of a drain pipe at Community Recycling. Upon arrival, I (Company 54) looked down into the cement drain pipe. I confirmed the en route reports that there were two pts collapsed in the bottom of the pipe. This vertical pipe was approximately 10 feet deep and 3 feet in diameter. I yelled down to the men in the pipe and did not get a response. Several nearby employees stated that the men were "passed out" for approximately 15 minutes prior to our arrival.

I named the incident the "Wheeler Incident" and assumed IC. E51 arrived on scene and a rescue plan was discussed. To mitigate the potential inhalation hazard, SCBAs were used. We removed a ladder that was previously in the pipe, and replaced it with a 14' roof ladder. Engineer 51 donned a SCBA and climbed down the ladder to make pt contact and secure each pt with a SCBA pack (without bottle) for hoisting. The balance of 51's and 54's crew acted as a haul team once the rope was securely fasten to the pts. The personnel at grade level near the top opening of the pipe was also equipped with SCBAs.

While setting up the extrication of the first pt, Batt 4 and USAR 52 arrived on scene. I briefed Batt 4 on our current rescue operation and he took command. He then assigned me "Operations" and Company 52 "Rescue Group". The IC cancelled HM66 and cancelled the air ambulance standby. E55 arrived on scene and was assigned to assist ambulance crews with pt care.

Shortly after both pts were extricated, a third pt whom was not inside the pipe required medical aid for chest pain. I assigned Company 55. See EMS narrative for pt care information.

Apparatus - USAR52	
Apparatus Arrival Date and Time	11:43:07 Wednesday, October 12, 2011
Apparatus Clear Date and Time	14:10:00 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	1
Apparatus Use	1
Apparatus Type	72 - Urban search & rescue unit
Personnel 1	K0972 - Whisnand, Seth
	Position: FE

Apparatus - E54	
Apparatus ID	E54
Response Time	0:10:11
Apparatus Dispatch Date and Time	11:31:21 Wednesday, October 12, 2011
En route to scene date and time	11:32:56 Wednesday, October 12, 2011
Apparatus Arrival Date and Time	11:43:07 Wednesday, October 12, 2011
Apparatus Clear Date and Time	14:09:59 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	3
Apparatus Use	1
Apparatus Type	11 - Engine
Personnel 1	K0747 - Knaggs, Jason E
	Position: FC
Personnel 2	K0823 - Reimers, Bevan C
	Position: FE
Personnel 3	K1065 - Buck, Nathaniel
	Position: FF

Apparatus - E51	
Apparatus ID	E51
Response Time	0:12:22
Apparatus Dispatch Date and Time	11:31:21 Wednesday, October 12, 2011
En route to scene date and time	11:31:43 Wednesday, October 12, 2011
Apparatus Arrival Date and Time	11:44:05 Wednesday, October 12, 2011
Apparatus Clear Date and Time	13:44:33 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	3
Apparatus Use	1
Apparatus Type	11 - Engine
Personnel 1	K0643 - Crider, Martin R
	Position: FC
Personnel 2	K0669 - Padilla, Anthony
	Position: FE
Personnel 3	K1095 - Busby, Jordan J
	Position: FF

Apparatus - KB4B	
Apparatus ID	KB4B
Apparatus Dispatch Date and Time	11:31:21 Wednesday, October 12, 2011

Kern County

Apparatus - KB4B	
Apparatus Arrival Date and Time	11:54:14 Wednesday, October 12, 2011
Apparatus Clear Date and Time	13:43:54 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	1
Apparatus Use	1
Apparatus Type	90 - Single Resource OCA
Personnel 1	K0469 - Brothers, Vernell D
	Position: FBC

Apparatus - E55	
Apparatus ID	E55
Response Time	0:23:38
Apparatus Dispatch Date and Time	11:36:57 Wednesday, October 12, 2011
En route to scene date and time	11:37:27 Wednesday, October 12, 2011
Apparatus Arrival Date and Time	12:01:05 Wednesday, October 12, 2011
Apparatus Clear Date and Time	13:50:16 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	3
Apparatus Use	1
Apparatus Action Taken 1	32 - Provide basic life support (BLS) KCFD
Apparatus Type	11 - Engine
Personnel 1	K0576 - Wells, Michael B
	Position: FC
Personnel 2	K0969 - Guerra, Luis A
	Position: FF
Personnel 3	K1009 - Machado, Thomas
	Position: .FE

Authority	
Reported By	K0747 - Knaggs, Jason E
	00:00:58 Thursday, October 13, 2011
Officer In Charge	K0469 - Brothers, Vernell D
	00:01:39 Thursday, October 13, 2011
Reviewer	K0747 - Knaggs, Jason E
	00:01:42 Thursday, October 13, 2011

Narratives	
Narrative Name	CO55
Narrative Type	Incident
Narrative Date	13:58:11 Wednesday, October 12, 2011
Author	K0576 - Wells, Michael B
Author Rank	FC
Author Assignment	1
Narrative Text	Eng 55 on scene, IC assigned us to patient care. First two pts assisted with CPR and packaging. ENG and FF rode in with first pt to assist with pt care. CO55 monitored a third pt with Engr 54 until 3rd amb on scene.
Narrative Name	HM66
Narrative Type	Incident

Person Involved - Baldwin, Robert	
Last Name	Baldwin
First Name	Robert
Business Name	Community Recycling
Street Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241
Phone	6613036207

Person Involved - Bartlett, Jimmy	
Involvement Code	MAINT
Last Name	Bartlett
First Name	Jimmy
Business Name	Community Recycling
Street Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241
Phone	6613301309

Person Involved - Flores, Eduardo	
EMS Patient	Yes
Involvement Code	EMP
Last Name	Flores
First Name	Eduardo
Business Name	Community Recycling
Street Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241

Person Involved - Martinez, Jose G	
EMS Patient	Yes
Involvement Code	EMP
Last Name	Martinez
First Name	Jose
Middle Initial	G
Business Name	Community Recycling
Street Address	1261 N WHEELER RIDGE RD
City, State Zip	KERN COUNTY, CA 93241

Person Involved - Ramirez, Eladio	
EMS Patient	Yes
Involvement Code	EMP
Last Name	Ramirez
First Name	Eladio
Business Name	A & B Harvesting
Street Address	1552 Royal ST
City, State Zip	Arvin, CA 93203

Person Involved - Starkey, Dan	
Involvement Code	FLD
Last Name	Starkey
First Name	Dan

Person Involved - Starkey, Dan	
Business Name	KC Environmental Health
Street Address	

Apparatus - HM66	
Apparatus ID	HM66
Apparatus Dispatch Date and Time	11:41:21 Wednesday, October 12, 2011
En route to scene date and time	11:42:22 Wednesday, October 12, 2011
Apparatus Clear Date and Time	12:06:34 Wednesday, October 12, 2011
Apparatus priority response	Yes
Apparatus cancelled after dispatch	Yes
Number of People	5
Apparatus Use	1
Apparatus Action Taken 1	93 - Cancelled en route
Apparatus Type	93 - Haz Mat unit
Personnel 1	K0746 - Duncan, Aaron S Position: FC
Personnel 2	K0606 - Romero, Anthony R Position: FE
Personnel 3	K0888 - Pudiwitr, Dustin E Position: FE
Personnel 4	K1052 - Sandoval, Nicholas R Position: FF
Personnel 5	K1099 - Lichenstein, Matthew E Position: FF

Apparatus - E52	
Apparatus ID	E52
Response Time	0:14:05
Apparatus Dispatch Date and Time	11:29:02 Wednesday, October 12, 2011
En route to scene date and time	11:29:02 Wednesday, October 12, 2011
Apparatus Arrival Date and Time	11:43:07 Wednesday, October 12, 2011
Apparatus Clear Date and Time	14:10:00 Wednesday, October 12, 2011
Apparatus priority response	Yes
Number of People	3
Apparatus Use	1
Apparatus Type	11 - Engine
Personnel 1	K0623 - Linville, Kain M Position: FC
Personnel 2	K0925 - Lomeli, David J Position: FF
Personnel 3	K0972 - Whisnand, Seth Position: FE

Apparatus - USAR52	
Apparatus ID	USAR52
Response Time	0:14:05
Apparatus Dispatch Date and Time	11:29:02 Wednesday, October 12, 2011
En route to scene date and time	11:29:02 Wednesday, October 12, 2011